METALLURGIA

THE BRITISH JOURNAL OF METALS

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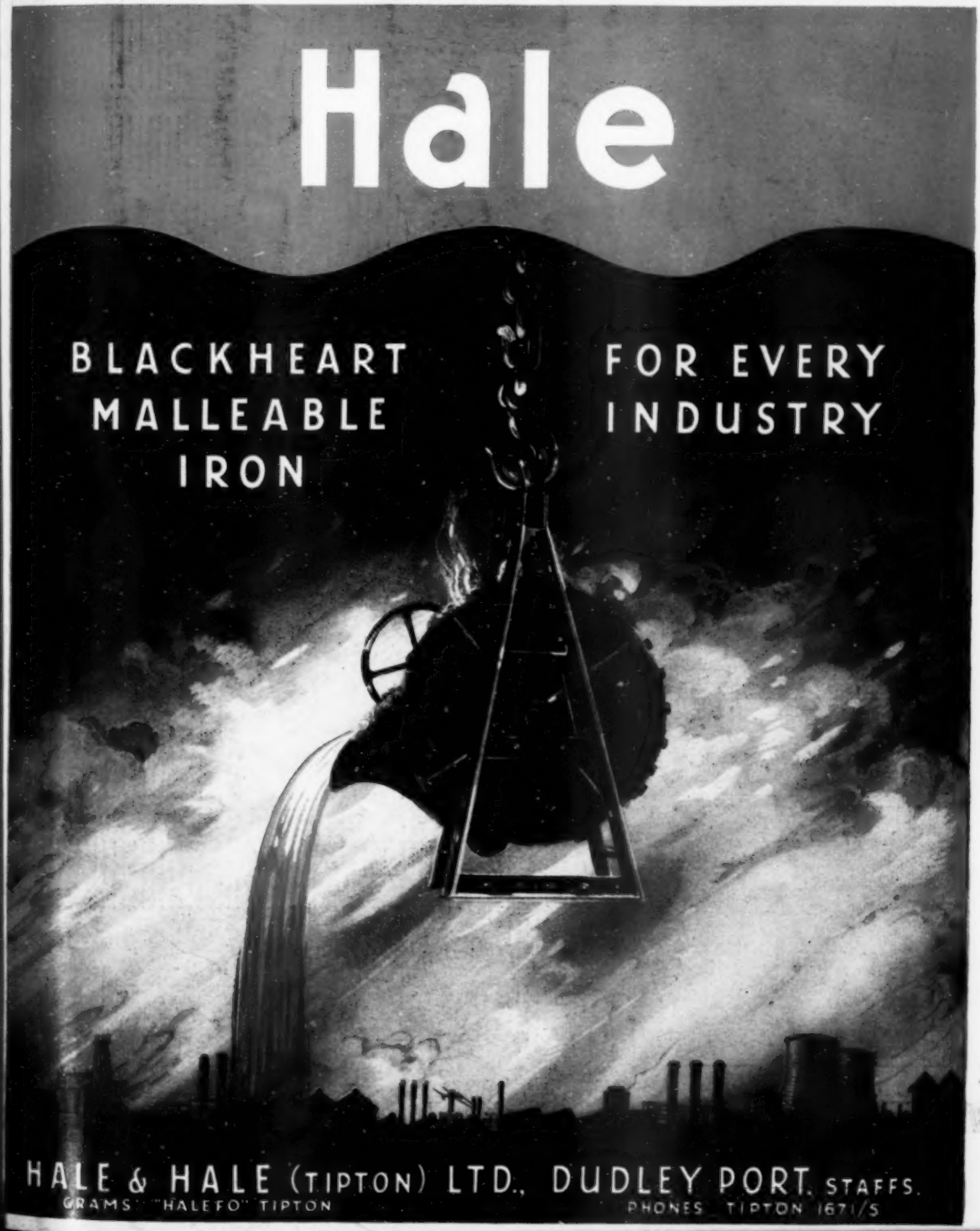

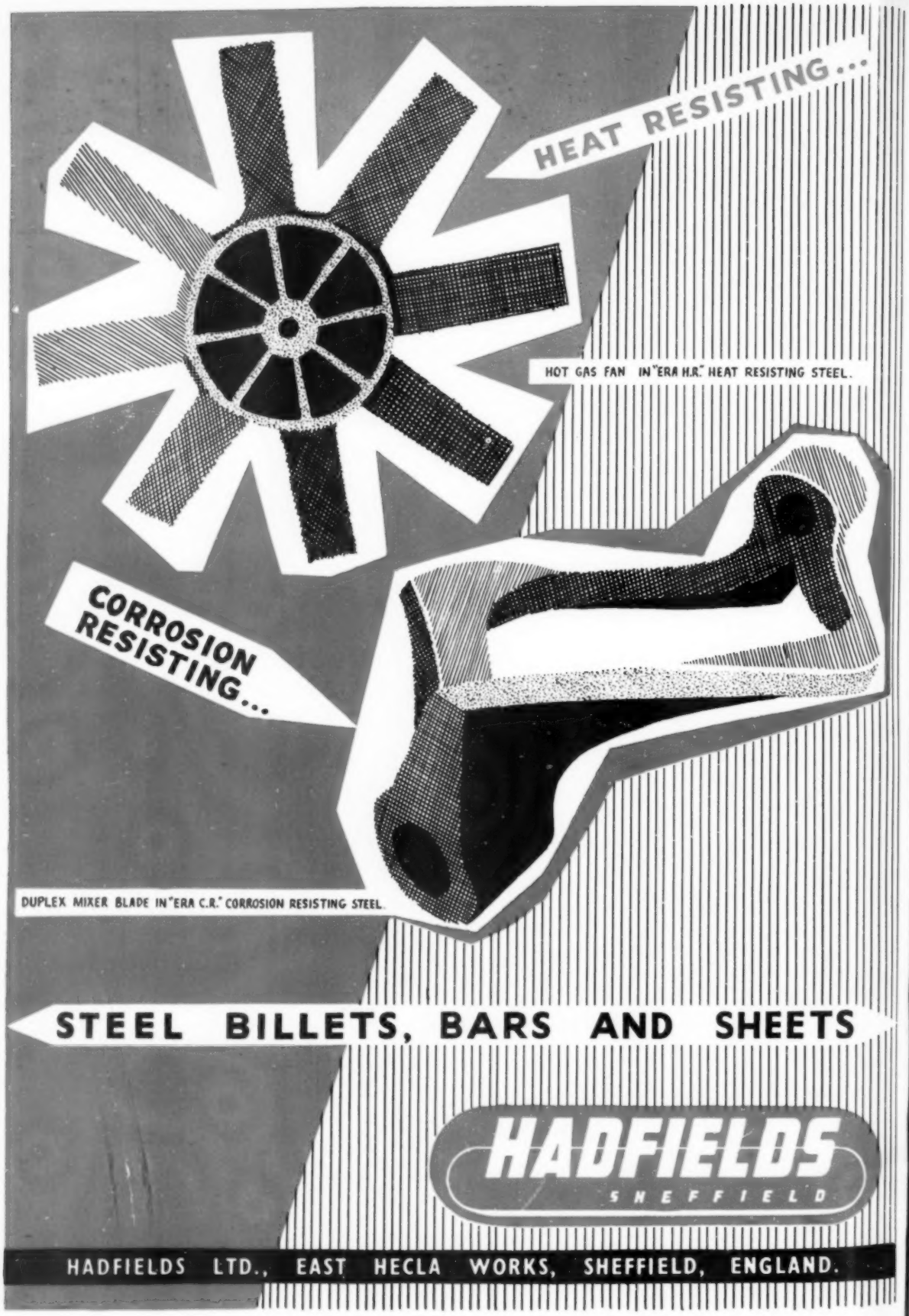
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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

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Electricity Generation

IT is very largely true that—as was pointed out by Sir Josiah Eccles in his recent Presidential Address to the Ninth British Electrical Power Convention—the electrical industry, whilst being in the front line of the export drive, is also responsible for creating the conditions in which other industries may expand and prosper. Without adequate supplies of electricity, the industrial expansion necessary for our economic progress will be impossible.

Some measure of the progress made in the expansion of the electricity supply industry itself is given by the fact that the amount of electricity generated today is double that produced nine years ago. In 1947 the new generating plant brought into service in the United Kingdom had an output of only 370 MW., but this figure has shown an annual increase until, in 1956, no less than 1,937 MW. new plant was added to the total—equivalent to the opening of a station equalling Calder Hall's full output once a fortnight.

By improved efficiency over the last nine years, some 31 million tons of coal have been saved, and electrical plants now coming into service will generate nearly one and a half times as much electricity per ton of coal as was generated on the average in 1956. Apart from fuel considerations, the large new generators have enabled designers to get much more output from each ton of steel or copper used in their construction. As an example, in the 200 MW alternators there is only 22½% of the copper and 50% of the steel per megawatt of output, compared with that used in the 30 MW. alternators of a decade ago. Raw copper and iron ore are imports and, hence, the better use of these materials by the designer is not only reducing the cost of his product but is making a direct contribution to the solution of our balance of payments problem.

In both the improved efficiency and the weight reduction, the metallurgist has played an important role, particularly in the development of the steels with improved creep resistance which have made possible the advances in operating temperature necessary to achieve more economical operating results. Perhaps even more important—and certainly more spectacular—is the solution of the metallurgical problems arising in the construction of nuclear power plant, where design requirements are constantly changing as new types of reactor are made possible by progress in fundamental and applied research.

So far as the gas-cooled thermal reactor is concerned, development must lie along two paths—firstly, increasing the surface/volume ratio of the fuel element, to increase heat ratings per ton of fuel, and secondly, a move to higher temperatures, both to increase heat ratings and to increase thermal efficiency throughout the plant. For technical reasons, these two steps might well be concurrent, since the first would demand a canning material of lower neutron absorption cross-section, for which beryllium seems the probable choice, and the use of beryllium could lead to the use of higher gas temperatures. To obtain the full benefit of the high temperature characteristics of beryllium, it may be necessary to use non-metallic compounds of uranium as fuel, and also to ensure that high temperatures do not adversely affect the graphite of the core or the steel of the pressure vessel. All these changes from the present designs will almost certainly necessitate the use of enriched uranium to different degrees, and the eventual end to this series of designs is the high temperature gas-cooled reactor now being studied at Harwell.

For large-scale power station use, investigations are proceeding into other types of reactor which might be feasible for completion in the mid and late 1960's. At a late stage, perhaps in the late 1960's, a whole new range of economic designs is likely to appear. The general trend will be for the degree of enrichment of the fuel to increase, and for the core size of the reactor to decrease. This will tend to lead to a steady reduction in capital cost per kilowatt, and to difficult engineering problems in removing large quantities of heat from small volumes, which in most cases will necessitate the use of liquid metal coolants.

There is a tendency to regard the advent of nuclear power stations as the end of the coal-fired boiler era, but although the deficiencies in coal for electricity generation will be made good in the first place by the burning of oil and later by energy from nuclear sources, coal is still the main source of basic energy for this country, and will remain so for many years. Eventually it seems likely that nuclear energy will be the main source of power, but it will take time for this stage to be reached: the new techniques will have to be mastered step by step.

The early nuclear reactors will have to be operated at the highest practicable load factors, and every effort will have to be made to ensure that reactors have a useful working life of at least twenty years, if the cost per unit of electricity is to come within the competitive range. Since only about 15% of the national electrical load is continuous, it would not be economically practicable at present to have much more than 20% of the generating capacity energised by nuclear reactors. When the need to step up this proportion arises, the electricity load may be flattened somewhat by the extensive adoption of three shift working throughout industry, by extending the use of storage heating and air conditioning, and by pumped storage.

It is clear that a very great reduction in capital cost per kilowatt will be needed before nuclear stations can compete with conventional stations at very low load factors, and although there seems little doubt that the total generation costs for nuclear power stations will continue to fall rapidly for a number of years, it is far from certain that only nuclear stations will be built after the late 1960's: it may be that it will be economically desirable to build conventional stations for peak load operation for many decades to come.

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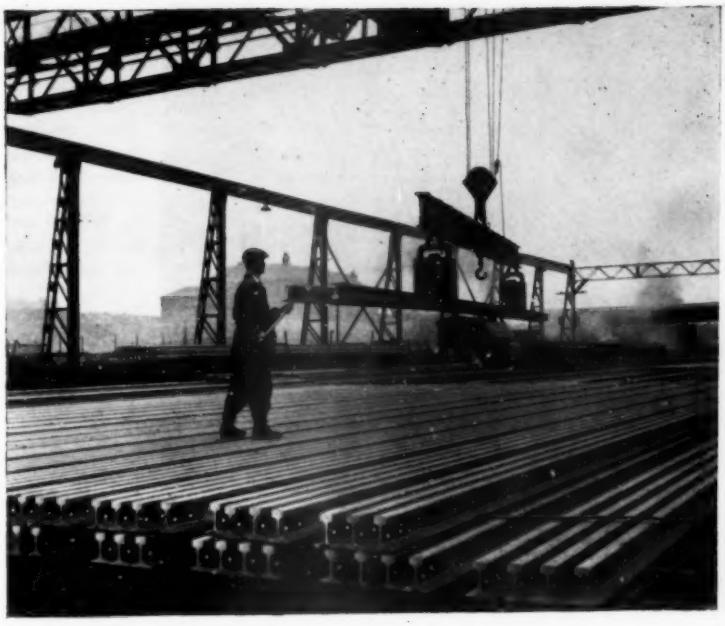
(Continued on page 25)

Permanent Way Material Production

United Steels' Workington Plant



Loading rails on to bogie bolster wagons.

NEARLY one third of this country's requirements of permanent way materials are supplied by the Workington Iron and Steel Company, which last year celebrated its centenary. As a result of modernisation and reconstruction schemes carried out over the last decade, this branch of United Steel Companies, Ltd., is now producing, in addition to a large output of pig iron, some 280,000 tons of steel ingots each year. The railway equipment produced from that includes some 145,000 tons of rails and 2,500 tons of steel sleepers, together with considerable tonnages of soleplates and fishplates. A remarkable feature of the Company's activities is that no less than 35% of the total production is exported.

Iron making from the local deposits of high grade hematite iron ore was already well established when Sir Henry Bessemer patented his revolutionary invention of the process that bears his name in 1856. A forerunner of the Workington Iron and Steel Company played an important part in the development of that process, as the pig iron produced from the local ores was particularly well suited to Bessemer's purpose and was described by him as the " purest iron of all." Rails at Workington are still made from acid Bessemer steel, its virtues having been proved in railway track for close on a century.

The works today represent a stage in the process of continuous evolution and change. Whilst there will always be some major piece of plant about to be replaced or reconstructed, in its present form it represents the culmination of several schemes in the last decade which have changed its face visibly and made it one of the most efficient of its type and size in the world. These schemes have involved an expenditure of some £5 million, and almost all sections of the works have been concerned in them.

The plant of the Workington Iron and Steel Company is an integrated one ; i.e. it utilizes its own resources as far as possible from the raw materials to the finished production, ancillary products of one stage being used at a later state to give a balanced process. The company mines iron ore and limestone, makes its own coke in batteries of coke ovens, uses the coke and limestone to smelt the ore in blast furnaces to make iron, and converts the molten iron to steel in the Bessemer plant. Ingots of steel are then rolled in the company's mills to take their final shape before despatch to customers.

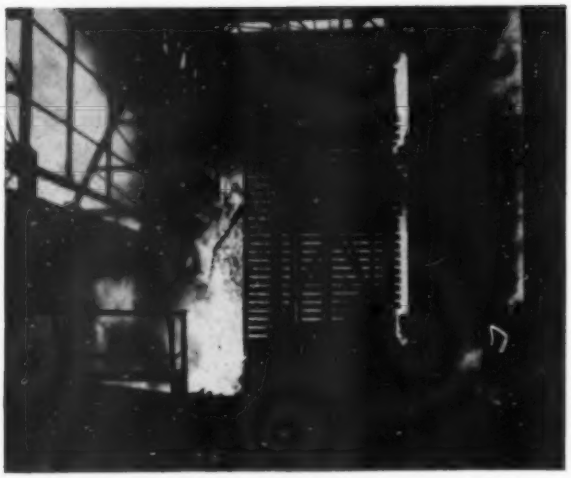
Large volumes of combustible gases are obtained from the coke ovens and the blast furnaces which are utilized as fuel for the generation of steam and for various metallurgical processes. From these sources come all the fuel requirements of the works ; except for a small quantity of coal required for mobile equipment such as locomotives and cranes.

Thus, not only are the fuel and power requirements of the works met from the coal originally charged into the coke ovens, but there is actually a surplus of coke oven gas sufficient to supply the domestic and industrial needs of a considerable area of West Cumberland.

Coke Oven Plant

The coking plant comprises 64 Woodall-Duckham Becker compound regenerative ovens, in two batteries, with a total throughput of 10,000 tons of coal per week. The remainder of the plant consists of coal handling, stocking and blending systems, chemical recovery plant and a benzole refinery. The first battery of 53 ovens came into service in 1936 and the second battery of 11 ovens in 1948. At the present time a new battery of 53 ovens is nearing completion : this will replace the original battery and will be similar to it.

Coal supplies are drawn from the local Cumberland coal-fields and blended with further supplies from Durham and South Wales, the high volatile content of the local coals being tempered by the lower content of the others to produce a strong coke suitable for the blast furnaces.



Pushing an oven of red-hot coke.

Coal is taken to the blending bunkers, and from there either to the mechanised coal stockyard, which is capable of holding 15,000 tons of blended coal and acts as a reservoir to cover colliery holiday periods—or to the crushing plant. The crushers reduce the raw mixed coal to 85% below ⅛ in., the most suitable size for carbonization, and a belt conveyor system takes the crushed coal up to the main service bunker.

While the two batteries of coke ovens are actually separated by the central coal bunker, the same machines service both. The ovens are 41 ft. long by 13 ft. high with an average width of 16 in. tapering 2 in. from the coke side to the machine side : they hold approximately 14·5 tons of crushed coal each. Every tenth oven is discharged in rotation, this schedule enabling the temperature of the battery to be maintained evenly. The heating flues of the ovens are fired by coke oven gas, the temperature being maintained at 1,320° C. by pyrometric control. Average carbonising time of each coal charge is 16½ hours.

After discharge from the oven, the coke is taken to a quenching tower, where a measured quantity of water is discharged on to it. From the tower, it is returned to a wharf for drying out. Rubber belts then convey it to a coke screening station from which coke over 1¼ in. goes by direct belt to the blast furnace bunkers. The undersize coke is crushed further for use as a fuel in the sinter plant and for mixing with the coal charged into the ovens.

Gas is drawn from the coke ovens by means of steam-turbine-driven exhausters, and is first cooled to condense the tar and moisture which it carries. The moisture condenses as ammonia liquor, which is collected and distilled to liberate the ammonia, this being returned to the gas stream, which is then passed through dilute sulphuric acid in lead-lined vessels known as saturators. Ammonium sulphate is formed in the saturators and is recovered in crystalline form.

After further cooling, the gas passes through a series of tower scrubbers, where it meets a descending stream of creosote which absorbs benzole from the gas. Subsequent distillation of the creosote separates the benzole from the creosote, the latter being then cooled and returned to the scrubbers.

On leaving the scrubbers, the gas is collected in a 3,000,000 cu. ft. holder, whence it is distributed to the various consuming points. Coke oven gas production amounts to some 15,000,000 cu. ft. per day. Approximately 12,000,000 cu. ft. are consumed within the works for oven heating, steam raising, and metallurgical purposes, the balance being made available to the local gas grid and nearby industrial units.

The crude coal tar is refined in a nearby plant through a Wilton still, the throughput of which is 450 tons per week ; crude benzole is refined to produce various grades of benzene, toluene and xylene and related products.

Ore Preparation

Supplies

Cumberland iron ore is mined five miles south-east of Whitehaven by the Beckermet Mining Co., Ltd., a subsidiary of The United Steel Cos., Ltd., and one of the two remaining mining companies operating on the concealed hematite ore field in this locality. The shafts are situated at Beckermet and Haile Moor, which together yield about 2,500 tons of ore per week. The quality of this ore is high, averaging 47% Fe, 15% SiO_2, 3% CaO, 0·5% S, and 0·01% P.

For a number of years the supply of Cumberland hematite iron ore has not been sufficient to satisfy requirements, and similar ores have been imported from Scandinavia, southern Spain, and North Africa. These ores are of a quality comparable to indigenous supplies in iron and phosphorus content. Typical figures are :

	Fe %	SiO_2 %	CaO %	S %	P %	Mn %
Ouenza	50	3	6	0·06	0·007	1·8
Zaccar	47	4	5	0·04	0·020	1·4
Rif	63	4	0·5	0·20	0·025	0·2
Alquife	49	5	6	0·05	0·013	1·5
Sydvaranger	60	8	0·5	0·04	0·010	0·1

Imported ores are brought direct into the Workington Dock, a statutory undertaking which can accommodate 10,000-ton vessels and is equipped with six 5-ton electric cranes and two 7-ton cranes. The ore is loaded into wagons and despatched by rail to the ore stocking ground at the works. Manganese and manganiferous ores for the production of ferro-manganese and spiegel also arrive at the dock from India, West and South Africa, and Russia.

Limestone is required to flux the siliceous material in the ores and the company operates its own quarry at Rowrah, from which all requirements of the blast furnaces are met. This quarry is equipped with modern drilling machines and diggers and a new crushing and grading plant, to which a washery for the production of clean stone for aggregate and ballast has recently been added.

Ore Preparation Plant

Modern blast furnace practice calls for an ore burden of uniform grading for size, and all incoming ores pass through a preparation process to meet such a requirement. After weighing, the ores are transferred by belt conveyors to the crushing plant where, by means of a jaw crusher and primary screens followed by a cone crusher, they are reduced to a maximum size of 3 in. Following this, further screens separate the material below ⅜ in. or ½ in. as required ; this then passes to the sintering plant. The screening plant also provides for the separation of a proportion of the ore between 1¼ in. and ½ in. for use as " bedding " in the sintering process.

The oversize ore leaving the final screening stage may be directed either to the ore stockyard or direct to the blast furnaces, distribution being effected by means of a 50-ton capacity transfer car.

Sintering Plant

The sintering plant consists of a three-pan Greenawalt installation with a capacity of 900 tons of sinter per day. Undersized ore from the screening plant, flue dust, undersized sinter screenings, and coke breeze are fed in predetermined amounts to a mixer where water is added in controlled quantities from a spray. The mixture is delivered to the top of the plant together with a supply of " bedding " from the screening plant. The charging car takes a supply of both and, as required, fills the empty pan with a layer of bedding on the pan bars followed by the sinter mixture. After ignition from a gas-fired hood, the sintering action, maintained by a strong suction, proceeds progressively throughout the depth of the pan ; when sintering is complete, the pan is inverted to allow the sintered mass to fall into a hopper below. The sinter is screened to remove undersized material and then drops onto a conveyor belt on which it is sprayed with water. The conveyor feeds the sinter to a stockpile from which it is taken to the furnaces by the transfer car.

In addition to the undersized ores from the screening plant, a proportion of purchased fine ore is used to balance the capacity of the plant against the irregularity of supplies from the crushing and screening of run-of-mine ores.

Blast Furnaces

The Workington blast furnace plant consists of three furnaces with hearth diameters of 20 ft., 16 ft. 6 in., and 15 ft. 9 in., respectively. The two larger furnaces together produce approximately 1,000 tons of hematite iron per day, while the third furnace is normally engaged on the production of ferro-manganese or spiegel—alloys of manganese and iron used in steelmaking. When one of the larger units requires relining, this furnace is burdened for the production of hematite iron.

25 ton Bessemer converter blowing.

20 ton electric arc furnace.

All the furnaces are of normal design with carbon hearth walls. Furnace stacks and hearths are lined with 40% alumina firebricks made from the company's own fireclay deposits at nearby Micklam, where an up-to-date plant for the production of refractories is installed. The largest furnace is equipped with a McKee distributor, while the other two furnaces are fed by a bucket hoist. All charging gear is interlocked and electrically operated.

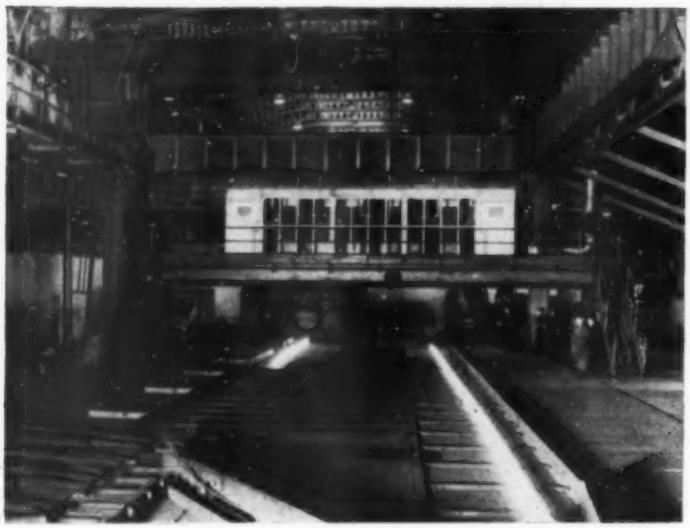
Each furnace has three hot blast stoves, and the air blast is maintained at a temperature of 1,400° F. on the hematite iron furnaces and 1,800° F. on the ferro-manganese furnaces.

The hematite iron furnaces are tapped at approximately five-hourly intervals on a strict schedule, to ensure a uniform supply of iron to the steelworks. The ferro-manganese furnace is tapped on a similar schedule. About 100 tons of iron are produced per cast and conveyed in 50-ton ladles to the mixer in the Bessemer shop. Great care is taken to ensure that, while casting, there is the minimum time off blast, so that the gas supply to the whole plant, which is fully integrated on gas supplies, is not jeopardised. Major plant renovations or alterations are arranged at week-ends when the steelworks gas requirements are very low.

Ferro-manganese is taken direct to the pig caster for casting into slabs weighing approximately 80 lb. each. This is a twin strand machine with a capacity of 100 tons per hour. It comes fully into use at week-ends, or at other times when the steelworks do not require the molten iron.

To produce 7,000 tons of iron per week calls for 13,000 tons of iron ore, 6,000 tons of coke, and 1,500 tons of limestone, while 1,100 tons of ferro-manganese per week calls for 2,200 tons of ore and 1,900 tons of coke. A total tonnage of 4,000 tons of slag per week is produced, and this is at present disposed of by tipping near the foreshore.

Blast furnace gas production totals 140,000,000 cu. ft. per day, and all this has to be freed from its dust content,



General view of rail mill, showing roughing and finishing stands.

which in the case of gas from the ferro-manganese furnace is relatively high. This is done by washing with water in towers, followed by passage through high-speed disintegrators : a final dust content of 0·04 grains/cu. ft. is obtained. Part of this gas goes to the hot blast stoves for heating the air blast, while the remainder goes to the boiler plant for steam raising for blast and power generation, and to the steelworks furnaces.

The central boiler plant consists of four modern Stirling water tube boilers, each with a maximum continuous rating of 100,000 lb./hr. of steam at 400 lb./sq. in. and 700° F. Coke oven gas and liquid fuel can be used to supplement or replace blast furnace gas.

There are four blowers for the blast furnaces, the first of which, newly installed in 1956, is a B.T.H. blower capable of blowing 62,000 cu. ft./min. at 18 lb./sq. in. pressure. Other units are two blowers rated at 45,000 cu. ft./min. at 15 lb./sq. in., while there is a standby unit of 35,000 cu. ft./min. capacity at 13 lb./sq. in. pressure.

Electric Power

The works generating plant of 20,000 kW. total capacity operates in parallel with the national grid system, and this permits a two-way interchange of energy. When there is a deficiency of coke oven and blast furnace gas at the boilers, power is imported ; when there is a surplus, it is exported. The annual power generated is 80 million units, of which 13 million are exported to the national grid system. Imported power from the grid totals 26 million units per annum. The maximum works electric power demand is 19,000 kW., of which up to 16,500 kW. has been taken from the grid during " off peak " demand periods ; during " on peak " periods this latter amount is limited to 5,000 kW.

Steelmaking Plant

The steel making units at Workington are two 25-ton acid Bessemer converters and one 20-ton electric arc furnace. Acid Bessemer steel represents the greater part of the production, some 5,000–6,000 tons of steel being made each week in the two converters. The arc furnace is used to supplement the Bessemer plant, and also to make certain special qualities of high-grade steel. The two steelmaking processes enable the company to satisfy a very wide range of requirements from its own resources.

Bessemer Process

After being transported from the blast furnaces in a ladle car, the hot metal is transferred to a 400-ton mixer in the converter shop. The function of this mixer is twofold : to act as a storage reservoir and to even out slight variations in iron composition from successive tappings of the blast furnaces, so that a thoroughly uniform metal is fed into the converters.

The shell of each Bessemer converter is lined with silica bricks, and with an acid lining such as this it is not possible during the steel making process to remove any phosphorus from the iron. This is one important reason for using only iron made from high-grade hematite ores, low in phosphorus content.

The steel shell of the converter is mounted in a trunnion belt and can be rotated by two 125 h.p. motors, allowing it to be tilted during the sequence of operations so that the vessel can be lowered for charging and pouring, and raised to the vertical for blowing.

The bottom section of the converter, which weighs about 30 tons, contains 30 cylindrical " tuyeres " about 2 ft. 10 in. long. Each tuyere is perforated longitudinally with ten $\frac{1}{2}$-in. holes, and it is through these holes that a powerful blast of air is directed into the molten metal. The spaces between the tuyeres are filled with firmly rammed crushed firebrick, fireclay, and firebrick filler blocks, and the whole bottom section, which is nearly 3 ft. thick, is arranged for easy replacement, as it is subject to severe wear. Replacement becomes necessary after about 30 to 34 " blows," corresponding to a steel production of about 800 tons.

When the converter is ready for charging, 25 tons of molten iron are drawn from the mixer into a ladle suspended from a 100-ton electric overhead travelling crane. The metal is automatically weighed and is then poured into the mouth of the converter. Next, the air blast, supplied by a turbo-blower at a pressure of 25 lb./sq. in., is turned on, and the converter rotated into the vertical position. The iron immediately submerges the tuyeres, and the air blast blowing through the metal starts to oxidise the unwanted elements in the iron.

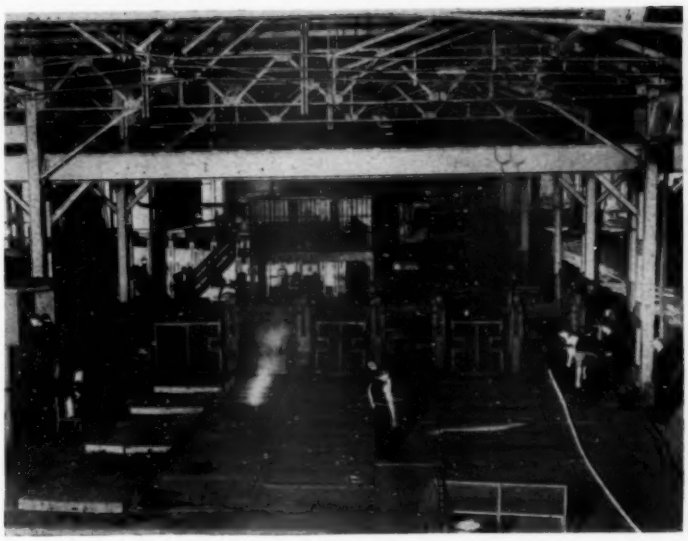
The " blow " begins with a shower of incandescent sparks, followed by a flame which grows in size and increases in brilliance as the blow progresses. Silicon and manganese are first converted by the oxygen in the air blast to their oxides, generating the necessary heat for the process. As their content in the metal is lowered, the oxygen attacks the carbon, with the evolution of carbon monoxide gas. Gradually, as the carbon is eliminated, the activity dies down and the flame suddenly drops, denoting the completion of the first part of the conversion of iron into steel, the operation taking about 15 minutes.

Its success depends very much on the skill and judgement of the operator—the " blower "—particularly towards the end of the blow. By following closely the

appearance and characteristics of the flame he is able to keep an accurate control over the temperature of the metal and the finishing point of the blow; these are most important.

When the blow begins, the temperature of the iron is about 1,300° C. As the silicon, manganese, and carbon are oxidised the temperature rises rapidly, and to prevent it going above the desired level the blower gives directions for small additions of steel scrap to be made. This scrap arises from off-cuts in the rolling mills, and as it is of the same type of steel as that being produced in the converter it does not affect the purity of the metal. As the end-point of the blow approaches and the flame dies down, the temperature of the steel has risen to about 1,650° C. An experienced blower can hold the finishing temperature to within a 20° C. temperature range over a series of blows.

When the Bessemer blow is completed, the converter is turned to the horizontal position and the air blast turned off. Any necessary additions of molten spiegel are now made to the vessel. The steel is poured into a ladle to which alloy additions are made as necessary to adjust the final composition. The ladle is then teemed into ingot moulds, the largest weighing about 3½ tons. Careful note of the temperature is necessary while the steel is being teemed, and the speed of teeming must also be closely controlled, as both factors have an influence on the physical condition of the steel ingot.



General view of the fishplate mill—a re-rolling mill for fishplates and bars.

Electric Arc Process

The 20-ton electric arc furnace has a basic lining. Supplies of scrap are available from within the plant in sufficient quantity to cover the entire requirements of the furnace, so that its steel production is as free from tramp elements as the acid Bessemer steel from the adjacent shop. The bulk of the tonnage goes to the rolling mills to supplement the Bessemer steel output, especially for high quality rails.

Rolling Mills

Rail Mill

Ingots from the Bessemer and electric steel plants are brought into the soaking pit bay and charged into four pits, each capable of holding 20 ingots. An ingot is withdrawn as required from the soaking pit by overhead crane and placed on a chariot which then takes it to the cogging mill approach rack. In this 36 in. mill, installed in 1949 and driven by a 3,250 h.p. D.C. variable-speed reversing motor, the ingot is reduced to the size suitable for the section currently being rolled, and then cropped at each end by an electrically operated shear; the crops arising here are returned to the Bessemer and electric furnace shops for remelting.

The bloom then enters the 32 in. two-high reversing roughing mill stand, which is driven by a 2,750 h.p. D.C. variable-speed reversing motor, installed in 1956. In this stand, the bloom is converted to the intermediate shape required for the finished section, and after approximately six passes is pushed across the mill floor to the finishing stand.

This 28 in. stand can be operated either as two-high reversing or three-high non-reversing, dependent on the section being rolled. To enable the bar to enter the upper rolling plane when rolling three-high, a hydraulically operated lift is situated at the delivery side of the stand. The drive is supplied by a 2,500 h.p. D.C. variable-speed reversing motor which, like the roughing mill motor, was newly installed in 1956.

After rolling, the bars are hot sawn or sheared to length. Rails are hot straightened on the cooling banks and then taken to the pre-straightener bay, while other sections are loaded to their respective finishing banks or plants.

The range and sizes of products of the rail mill are rails from 45 to 110 lb./yd., fish and bearing plate bars, sleeper plates from 11½ in. to 14 in. in width, and billets and slabs from 40 to 145 lb./yd., together with certain rail and sheet bar sections in high manganese steel. About 150,000 tons of rails are produced annually.

Fishplate Mill

This is a three-stand, three-high, 18 in. mill, consisting of first roughing, second roughing and finishing stands, driven by a 1,200 h.p. steam engine. Extensively modernised last year, the fishplate mill is equipped with a reheating furnace capable of 50 tons per hour throughput for the heating of 2½–5 in. billets and blooms required for the production of a wide range of fishplate bar sections, bearing plate sections, spring bars, rounds and other section. After hot sawing to length, the bars are fed on to cooling banks, from which they go to the finishing departments. The mill's output is approximately 11,400 tons per annum.

All the rolls for the rail and fishplate mills are turned in a roll turning shop, completed in 1955, which has ample space for the stocking of rolls.

Finishing Plant

Rail Finishing Plant

This plant consists of a 50 in. roller straightening machine, four rail drilling and ending machines, and

Simultaneously drilling and milling a rail end on a purpose-made machine tool.

Inspection of steel sleepers for accuracy of punching.

certain gag straightening machines. Here, rails are straightened, inspected, cut to length, drilled in the two pairs of machines and passed outside for customer's final inspection in the loading bays. Those for home railways are loaded direct on to bolster wagons for immediate despatch, while rails for overseas destinations are transferred to Workington Dock along the company's own line.

Steel Sleeper Plant

Although, in terms of tonnage, rail production is by far the most important activity of the Workington Iron and Steel Company, other permanent way materials are also manufactured on a substantial scale.

Steel sleeper bars are rolled either flat or trough-shaped, according to the type of sleeper being manufactured. After cooling they are transferred to the sleeper plant where they are cut into plates of the desired length. The plates pass slowly on a conveyor system through a heating furnace, attaining a temperature of some 850–900° C. Holes for the rail fastening are then punched into the plates under a hydraulically operated press. This operation is immediately followed by pressing to shape in a second similarly operated press.

Travelling along an open-air bench, the plates cool and any surface scale is removed with wire brushes. This is done to assure good adhesion of the protective coating which is applied when the sleepers reach the dipping shed. The still warm sleepers are dipped in a bath of rust-preventing medium and lifted slowly out by means of an endless conveyor. Inspection and gauging are undertaken before the sleepers are ready for despatch.

The output of the plant is between 25,000 and 30,000 tons of sleepers annually.

Fishplate and Bearing Plate Plant

Fishplates are the steel jointing iron pieces which hold the laid rails together end-to-end. Bearing plates, which are also known as soleplates, are the plates upon which the flat bottom rails rest on the sleepers.

Fishplate bars, produced in either the rail or fishplate mill, are transferred to the processing department, where the first operation is shearing into individual plates of the correct length. The plates are then heated in a furnace in preparation for punching the bolt holes by which they will ultimately be connected to the rails. Punching, notching (if called for) and straightening of the fishplates are carried out on two or three double-sided machines set in one line in extension of the reciprocating hearth of the reheating furnace. These machines are capable of performing the three operations in under one minute. For those customers who prefer the bolt holes to be drilled instead of punched, the plates are still reheated, then hot straightened and drilled when cold in a twelve-spindle multiple drilling machine.

For bearing plates, the production flow can be similar to that for fishplates. More often, however, bearing

(*Continued on page 37*)

General view of the processing line for re-heating, punching and straightening fishplates.

New Techniques Aid Metallurgical Research at the N.P.L.

By E. I. Brimelow, M.Eng., A.I.M., Assoc. I.Mech.E,

Industrial and Scientific Liaison Officer, National Physical Laboratory

A brief survey of the work of the Metallurgy Division of the National Physical Laboratory, based on exhibits on view during the recent Open Days. Aspects referred to include brittleness in iron, X-ray diffraction and radioactive tracer techniques, creep and fatigue, magnesium alloys, and the effect of fire on the tensioned wires of pre-stressed concrete.

ON Wednesday and Thursday, May 22nd and 23rd, the work of the National Physical Laboratory, Teddington, was on view to more than 3,500 visitors. In the Metallurgy Division, the interesting results obtained by improved X-ray techniques and the use of radioactive tracers in studies of the mechanism of failure of metals and alloys under direct and alternating stresses, were much in evidence. Besides the more fundamental aspects of the work, there was revealed an awareness of some of the more practical present day problems related to the use of ferrous and non-ferrous metals in nuclear and conventional power stations, and for other industrial applications.

Brittleness of Iron

The brittleness induced in high-purity iron by small amounts of nitrogen, phosphorus and other elements—after appropriate heat treatment—has been referred to previously in METALLURGIA.[1] The study of the behaviour of single crystals of iron under tensile stress at low temperatures (— 196° C.) has been extended, since it provides a useful means of determining the way in which the relative ease of deformation by slip (ductile behaviour) and by cleavage (brittle behaviour) may be modified by the presence of alloying elements in iron. Results for iron to which 0·05% of nitrogen had been added showed that, with nitrogen present in solution: (*a*) the yield strength was raised; (*b*) the cleavage strength was raised; and (*c*) the tendency towards brittle behaviour was more marked. With nitrogen present in the form of iron nitride: (*a*) there was little further effect on cleavage strength; (*b*) there was a marked increase in yield strength; and (*c*) there was a further tendency towards brittleness.

The susceptibility to grain boundary embrittlement of iron containing phosphorus, in amounts similar to those found in commercial steels, resembles to a certain extent that of temper-brittleness in heat-treated low alloy steels. The behaviour of an alloy of iron and 0·09% of phosphorus has been investigated at the N.P.L., using a simple radioactive tracer method to determine the segregation of phosphorus at the boundaries of embrittled iron. A typical brittle fracture is shown in Fig. 1. Active phosphorus was used to make the alloys and to enable the phosphorus content of successive thin layers of metal, which were removed from the fracture surface by etching, to be determined. The amount of phosphorus in the boundary was found to vary with the heat-treatment applied, and to be greatest when the heat-treatment was such as to induce brittleness. Concentration of phosphorus in the grain boundary region could be fifty times as great as within the grain, and the degree of intergranular failure was related to the amount of phosphorus contained within a grain boundary layer, about 1,000Å thick. It is evident from this work that a similar technique might be useful for investigating the more complex problem of temper-brittle steels.

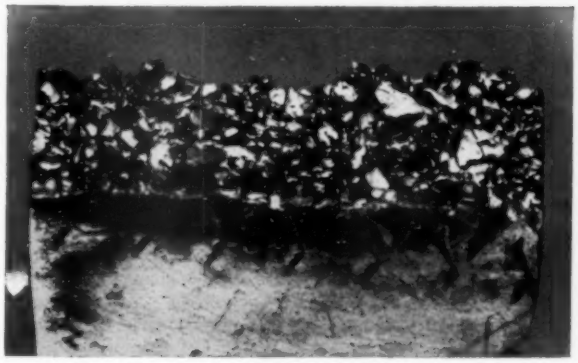


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Fig. 1.—A typical intergranular brittle fracture of an iron —0·09% phosphorus alloy after heating to 700° C. and water quenching. × 7½

Importance of Texture in Rolled Iron

Previous work[2] had shown that at —196° C. the tensile properties of single crystals of high purity iron were markedly dependent on orientation, and the results suggested that if a substantial proportion of the crystals of an aggragate had [100] planes normal, or near normal, to the direction of stress, the tendency to brittle fracture should increase. In more recent work, however, in which Swedish iron was rolled at various temperatures to produce bars with different textures, it was found that the variation in notch impact and tensile properties could not be explained entirely by differences in crystallographic texture. It is probably complicated by other factors, and further work is required to elucidate the anomalous behaviour of rolled iron having a very pronounced texture.

Application of New and Improved Techniques

X-ray diffraction techniques such as were used in the above investigation to determine textures of rolled iron have been applied to a study of the surfaces of steel spheres used in ball-bearings. Details of this investiga-

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Fig. 2.—Carbon extraction replica for a 2¼% chromium, 1% molybdenum steel specimen from a superheater tube after creep testing for 1,725 hours at 580° C. under a stress of 2¼ tons/sq. in. × 8,500

tion were described in METALLURGIA earlier this year.[3] It is an interesting example of the usefulness of this technique for examining industrial products, particularly when used in conjunction with other testing procedures; it also demonstrates the application of a direct-reading method using Geiger-Muller counters to record the measurements immediately, instead of the more lengthy procedure using photographic and photometering methods.

A new low-angle X-ray scattering camera has been built in which the X-ray beam is focused by reflection from two curved mirrors. It has been used to study the sub-microscopic changes in structure of metal foils which occur during the course of fatigue. The effects which are observed may be explained by assuming that disc-shaped cavities are formed parallel to the slip planes, during fatigue, and work is in progress to investigate the scattering pattern in greater detail in order to obtain more information regarding the shape and size of the cavities. A microbeam X-ray diffraction camera has also been developed for examining small selected areas of a specimen by either transmission or back reflection. It will be used to study structural variations such as differences in orientation between adjacent subgrains; the specimen area can be located for irridation within a few microns. In order to improve focusing of the electron beam to provide a sharper and more intense X-ray source, a new electron gun has been constructed for use with a micro-focus X-ray tube. The soft X-ray spectrograph has been modified to enable a copper-beryllium electron multiplier to replace the photographic plate for recording purposes. This new detector increases the sensitivity of the equipment and reduces the exposure time, so that there is less risk of the surface of the specimen under examination becoming contaminated during exposure.

The electron microscope has proved most useful for studying the changes of structure which take place in steels during creep tests. This work has emphasised the importance of precipitated particles of less than 1,000Å diameter. In particular, the carbon extraction replica technique has proved most useful. The advantage of this method is that all the particles loosened from the alloys by etching remain attached to the replica in the position they occupied in the alloy, so that in many cases it is possible to identify the particles by their electron diffraction patterns. The replica is prepared from a polished and etched specimen by evaporating onto the surface *in vacuo*, a layer of carbon 100Å thick. The specimen is then etched through the carbon replica, which is subsequently removed by an electrolytic process. The various particles remain adhering to the carbon replica and can be examined in the usual way. Fig. 2 shows a typical carbon extraction replica for a superheater tube steel after creep test.

In view of developments in the semi-conductor field, and in connection with zone-refined metals, there is an increasing need to analyse for trace impurities at low levels down to one part in 10^7, i.e., lower than is practicable with conventional analytical techniques. One of the most promising methods is that of neutron activation analysis, and this was demonstrated for the determination of small traces of impurities in high-purity aluminium. In connection with this work, a gamma scintillation spectrometer has been found very useful as a criterion of radioactive purity of the active species measured in these determinations. In certain cases, quantitative information of the amount of impurity present may be obtained directly without chemical separation.

Reference has been made already to the use of tracer techniques for investigations into the grain boundary embrittlement of iron-phosphorus alloys. Another interesting application of radioactive tracers was demonstrated in connection with the determination of the vapour pressure of chromium by a method combining the Knudsen diffusion cell with a radioactive tracer technique using Chromium 51. This method permits the measurement of vapour pressure down to 10^{-6} mm. Hg. The apparatus has been used to determine the vapour pressure of chromium, unalloyed and alloyed with metals such as iron, nickel, and aluminium, the reduction in vapour pressure enabling the activities in the binary systems to be obtained by calculation. The vapour pressure measurements will be combined with calorimetric measurements in order to determine phase boundaries at low temperatures in high melting point alloy systems, which is not possible with the normal method.

Creep and Fatigue

To meet the existing specifications for steels used in modern power plants, it is necessary to make long-term creep tests (of the order of 30,000 hours) to ascertain the ability of the material to withstand stresses at temperature. A factor determining creep behaviour of steels over these long periods is the structural changes which occur, and these are being studied at the Laboratory by electron-microscopy and electron diffraction, in addition to the more usual techniques. With this information it may be found possible to develop short-term tests which will enable the results of long-term creep tests to be predicted. As an example of this work, the changes in the microstructure of a 2¼% chromium, 1% molybdenum steel as used for superheater tubes were shown. In this case, the first effect of prolonged heating at 550° C. and above for 20,000 hours (2½ years) was the precipitation of fine particles of carbides; then followed a progessive coarsening of these particles, resulting in weakening of the steel.

In order to obtain information about mass structural

effects in relation to creep properties, an investigation, sponsored by the Electrical Research Association was made into the creep properties of a large rotor forging of molybdenum-vanadium steel. Such rotors are used in high-pressure steam turbines of modern power generating stations, and operate at conditions where creep strength is important. Creep tests were made with a load of 5 tons/sq. in. at 565° C. on specimens cut from the bore and periphery of the rotor. The results indicated that rotors oil-quenched from 970° C. and tempered at 680° C. for 8 hours had better creep properties than when air-hardened from 970° C. and tempered at 680° C. for 14 hours.

There has been renewed interest in the possible use of metal-ceramic mixtures as creep resisting materials for use in gas turbines and other high temperature applications. Heat-resistant alloys at present used consist essentially of a strong matrix in which fine particles are dispersed. This structure is obtained by heat treatment and may be destroyed by use at too high a temperature, which results in the fine particles dissolving in the matrix or growing in size, with serious effects on high temperature strength properties. There is, therefore, a limiting temperature at which alloys based on nickel, cobalt or iron can be used. The possibility of developing sintered mixtures of fine alumina particles embedded in a ductile nickel matrix is being investigated and certain general guiding principles for this work have been formulated.

The fatigue behaviour of an iron-phosphorus alloy with intergranular weakness has been studied. The type of intergranular fatigue fractures obtained would not have been recognised as fatigue fractures if the histories of the specimens had not been known, and the investigation showed that these fractures could occur in material having a normal tensile strength and ductility. Intercrystalline weakness in these iron alloys is sometimes, but not always, accompanied by an appreciable reduction in fatigue strength.

The effect of cyclic speed on the fatigue strength of mild steel at high temperature has also been investigated. It is usually found that the fatigue strength of metals is slightly reduced by decreasing the cyclic speed, the reduction becoming greater with increase in temperature. For mild steel, however, this speed effect is reversed at temperatures between 200° and 300° C. In this temperature range the fatigue strength was found to be considerably greater at 10 cycles per minute, and it is thought that this behaviour is caused by strain ageing.

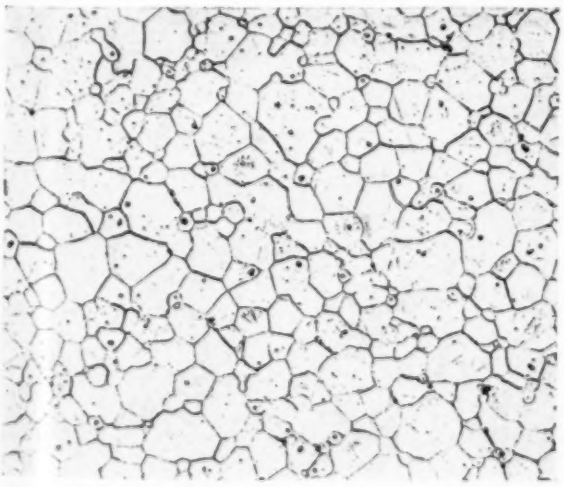

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Fig. 3.—Typical clean microstructure of chill cast magnesium—0·7% zirconium alloy made by the direct addition of zirconium metal and melting under argon. × 150

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Fig. 4.—Close-up of pre-stressed concrete beam after fire test at the D.S.I.R. Fire Research Station, showing fracture of cable of cold-drawn high tensile steel wires.

Magnesium Alloys

A renewed interest in the welding characteristics of magnesium base alloys containing 1–2% of aluminium and 0–0·5% of calcium has arisen from the use of these alloys for sheathing fuel elements in gas-cooled graphite-moderated reactors of the Calder Hall type. It has been suggested that cracking is associated with a second phase present at the grain boundaries in the weld zone. Investigations, therefore, had been undertaken to determine the magnesium-rich corner of the ternary equilibrium diagram in the solid state, since it was considered that this would assist in the interpretation of the weld structures.

An interesting development of the work on the constitution of the magnesium-zinc-zirconium alloys is a new method of making the alloys in which metallic zirconium in the form of machinings or powder is added directly by melting the metals together at 900–950° C. under argon in a solid steel crucible. No fluxes are used in this method, and the alloys made are clean and have good tensile properties. A typical microstructure is shown in Fig. 3. This direct method of adding zirconium appears to have advantages over the " master salt " and flux method generally used.

Effect of Fire on Tensioned Wires of Pre-stressed Concrete Beams

The use of pre-stressed concrete beams is now a common feature of modern building construction. Since the strength of these beams is largely dependent on the pre-stressing loads in the stressing wires, it has become increasingly important to know how they would behave during a fire in a building. A governing factor under these conditions would be the effect of temperature on the stressed wires and the extent to which they would

deform plastically, resulting in loss of pre-stress and leading, eventually, to the collapse of the beam. Fire tests carried out under standard conditions at the Fire Research Station, D.S.I.R., had shown that at failure the surface of the beam exposed to the flame exceeded 1,000° C., but that the wires attained a temperature of only about 400° C. A pre-stressed concrete beam which failed during these fire-tests in shown in Fig. 4. Two types of tests, therefore, have been carried out at the N.P.L. in support of this investigation. In the first series, commercially hard-drawn steel wires such as are used in pre-stressed concrete work were tensioned at 50% of their tensile strength and heated at the steady rate of 100° or 200° C. per hour until rupture occurred. At 350° C. marked creep occurred, leading to failure, and the results obtained corresponded with the times and temperatures for the failure of the beam in actual fire tests. The second series of tests was made to assess the damage to the wires. In this case, the loss of pre-stress was determined for wires tensioned at 60% of their tensile strength and heated at a constant rate of 200° C. per hour to various maximum temperatures. From these results, it was possible to assess the effect of fires of small magnitude, or of short duration. The work confirmed that pre-stressed beams are liable to collapse when the wire temperature reaches about 400° C., which would generally be attained in two to four hours from the commencement of a fire. Considerable losses in pre-stress however, may occur when the wire temperature has reached only 150° C. The results suggest the necessity for early control of fires in buildings having pre-stressed concrete beams, and suggest the importance of thermal-insulation to reduce the temperature attained by the tensioned wires in a fire; it would also be desirable to incorporate facilities to enable re-stressing of the wires after a minor fire.

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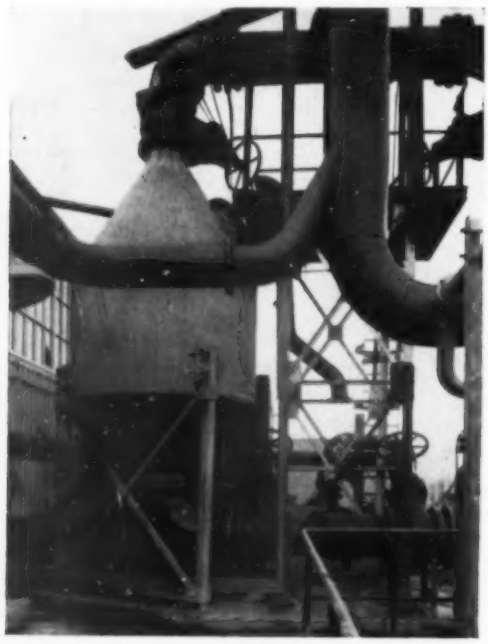
Largest Deoxo Purifier on Stream

WITH the start up recently of the British Oxygen Company's new air liquefaction plant at Middlesbrough, the largest Deoxo purifier so far installed in this country went on stream. One of the functions of this modern plant is to supply high purity nitrogen to the nearby Wilton Works of Imperial Chemical Industries, and B.O.C., after considerable experience with Deoxo gas purifiers in their various plants throughout the country, decided to use this process for removal of residual oxygen before piping the pure nitrogen to Wilton. The Middlesbrough Deoxo unit is capable of purifying very large quantities of nitrogen and, according to performance data so far available, the level of oxygen remaining in the gas after purification is well within the specification guaranteed by the manufacturers.



This D Type purifier is designed for the continuous removal of molecular oxygen from nitrogen by combining it with hydrogen to yield water vapour; the combination is effected over a precious metal catalysts which is highly active at room temperature, and the water vapour formed is removed in a standard dryer. Other types of Deoxo purifier provide for: (i) selective combination of oxygen with hydrogen in the presence of carbon monoxide; (ii) oxidation of carbon monoxide to carbon dioxide; (iii) oxidation of hydrocarbons to carbon dioxide; (iv) hydrogenation of carbon monoxide to methane; and (v) selective hydrogenation of acetylene in ethylene.

Although this purifier is the largest of its kind so far on stream in this country, larger units will be in use shortly, and comparable units have been in operation on the Continent for several years. The manufacturers of the Deoxo gas purification equipment—Baker Platinum Division of Engelhard Industries, Ltd.—are currently working on designs for purifiers with capacities up to 2,000,000 s.c.f.h.

Welsh Resources to be Surveyed

A SUGGESTION made by Dr. Clyde Williams, Director of the Battelle Institute, when he addressed a Trade Promotion Conference at Cardiff last October, that the economic resources of Wales should be surveyed, has been adopted by the organisers of the Conference, the Welsh Economic Development Council. It is proposed that a detailed survey should be undertaken of all the resources of Wales that might have a bearing on the economic development of the country. Particular attention will be given to the possibilities which exist for the exploitation of Welsh water resources. Wales has abundant supplies of water, and this is recognised by the Development Council as an asset of great importance in the development of the Welsh economy and the attraction of new industries.

The B.I.S.R.A. Performance Recorder

ACCURATE costing and efficient production planning both demand exact knowledge of machine performance. Machinery, especially heavy plant and machine tools, represents a substantial capital investment whose amortisation is directly related to the rate of employment. Exact information on working time, idle time, and the reason for stoppages, is therefore of considerable economic importance in encouraging maximum use and higher production. Some of this essential data can be obtained by automatic pen recording on moving charts, either of the "roll" or circular types. Analysis, however, is a formidable task, so time-consuming as to be uneconomic, and only too often the full value of the records concerned is not therefore properly exploited.

If the chart is replaced by paper tape and an automatic perforator is used to punch holes representing the information, the record can be made in a form suitable for automatic analysis by an electronic computer or by a simple relay analyser. This technique eliminates the tedium of analysis but, because the tape is running all the time that the machine is in operation, long tapes have to be fed into the analyser, and this takes time.

The performance recorder developed by B.I.S.R.A.'s Plant Engineering Division is based on a punched-tape recording system originally developed in connection with a study of crane movement, and carries automatic recording a step further. It summarises the operation of the machine and produces a condensed record for analysis. The way in which it works is best described by referring to equipment designed for the specific purpose of recording the operation of a rolling mill. Three operating conditions had to be recorded: *running time* (strip being rolled); *idle time* (mill stationary during production; threading new coils or changing screwdown and guide settings); *stoppage time* (mill out of production owing to roll change, failure of plant, or absence of operator).

Each order rolled by the mill is designated by an order number, against which running and idle times are allocated. Running and idle times are referred to as *chargeable time*. Stoppage time is referred to as *non-chargeable time*. The duration of each stoppage is allocated to one of the following causes: roll-changing; mechanical fault; electrical fault; operational defect; meal break; late start; early finish.

Fig. 2.—Push-button feed-in station.

The performance recorder (Fig. 1) has two "accumulators," each of which can be regarded as the electrical equivalent of the mileage recorder of a motor-car speedometer, but recording time instead of distance. One accumulator records running time, the other idle time. A clock incorporated in the equipment is arranged to provide electrical pulses at intervals of 3·6 seconds (1/1,000 hour). These pulses are automatically sent either to the idle time accumulator or to the running time accumulator, according to the position of a relay on the mill.

The operator has under his control a set of push-buttons (Fig. 2) for the purpose of recording on the tape the code number of each order or the stoppage code number. He also has an "incident button," and when this is pressed the data stored in the accumulators and on the push-buttons are punched in the tape and each accumulator and push-button station is reset to zero.

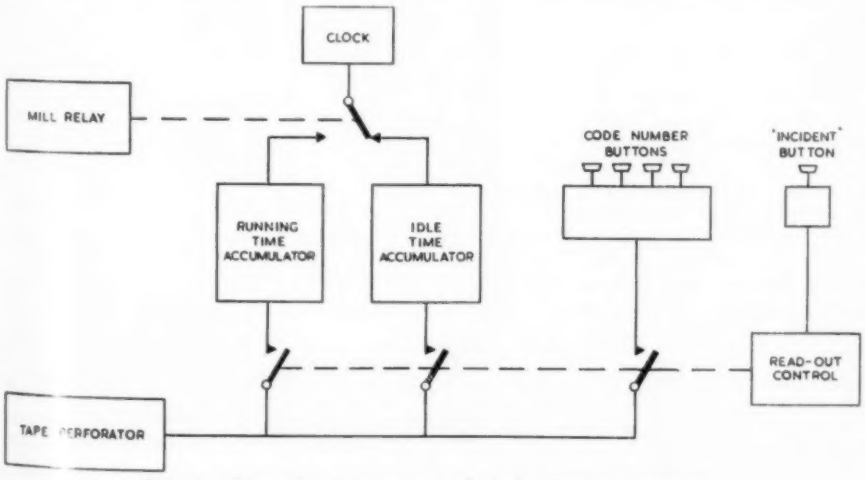


Fig. 1.—General arrangement of performance recorder.

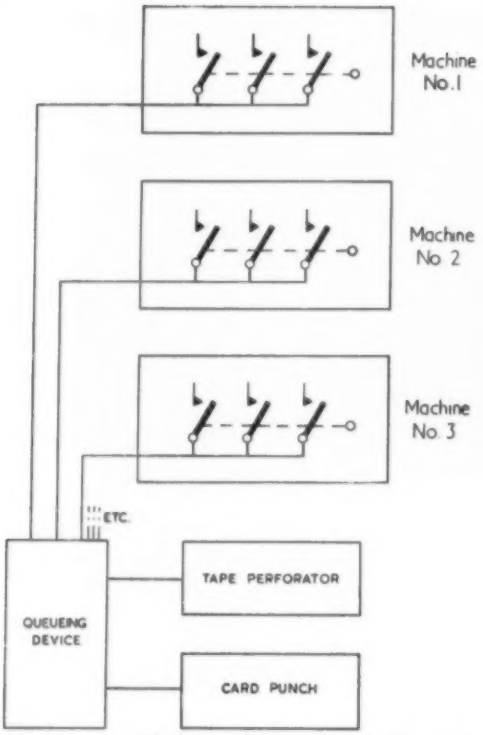


Fig. 3.—Installation with up to twenty-five performance recorders feeding a tape perforator and a card punch through a queueing device.

The Equipment in Use

The sequence of events during the rolling of an order is as follows :—

At the end of the previous order the operator will have pressed the " incident " button, thus emptying the previous contents of the accumulators on to the tape. Idle time will then have begun to accumulate in the idle time accumulator. When the new order is received, the operator sets up the order number on the code push-buttons. As soon as rolling begins, the time pulses are switched automatically from the idle time accumulator to the running time accumulator.

When one complete coil has been rolled, the mill is stopped while the next is threaded. During this period the clock pulses are automatically switched back to the idle time accumulator. When the mill starts rolling again the time pulses are added to those already stored in the running time accumulator.

This sequence is repeated for each coil until the order is completed. The operator then presses the " incident " button and both the total time for which the mill was actually rolling and the total idle time are removed from the accumulators and punched in the tape, together with the code number representing the order. The code number can be set up or changed at any time before pressing the " incident " button.

If a fault should occur during the rolling of an order, the operator presses the " incident " button, thus " emptying " the contents of the two accumulators on to the tape. When the cause of the stoppage is discovered he sets up on the push buttons the code number representing this particular fault. Once the fault is remedied he presses the " incident " button again, whereupon the duration of the stoppage and its cause are then punched in the tape. When rolling continues, it is only necessary for the operator to set up the order number once more on the push-buttons.

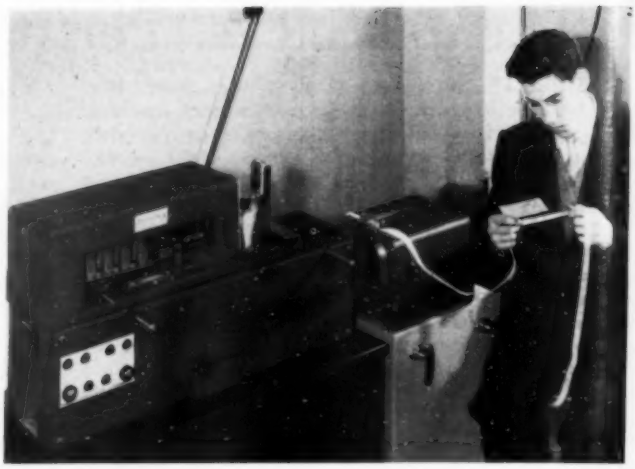


Fig. 5.—Punched-card and punched-tape reading station.

Analysis of the Tapes

The tapes can be analysed in several ways. As there are only ten different characters on the tape it can easily be " read " by eye if the expensive equipment for automatically reading-out or printing-out the results is not available. The data on the tapes can, however, be transcribed on to punched cards either automatically, by means of a tape-to-card converter, or manually. The

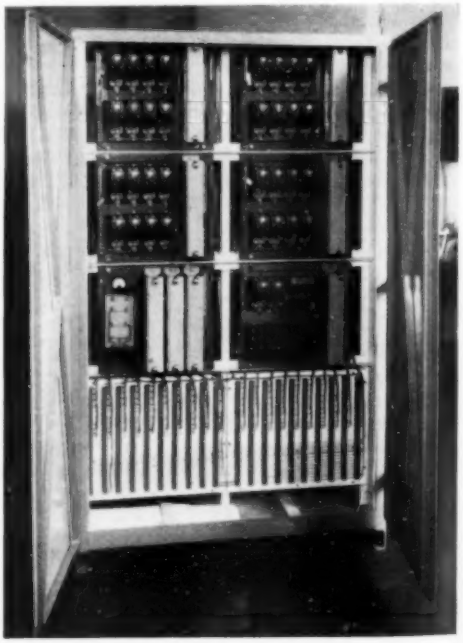


Fig. 4.—View of performance recorder showing accumulators and queueing device.

analysis can then be performed by punched card equipment. Alternatively, the data on the tape can be printed out by a standard teleprint page printer. If an electronic digital computer is available, the fullest analysis of the data and a detailed printed record can readily be obtained. This method has the advantage that data on tapes can be transmitted automatically from outlying factories to a computer at a central point.

The performance recorder is now being manufactured commercially by the Digital Engineering Co., Ltd., 136, Battersea Park Road, London, S.W.11. An installation to record the operation of eighteen machines has been built for a steelworks, and this installation incorporates several additional features. It has a queueing device that makes it possible to record the operation of up to twenty-five machines with a single tape perforator (Figs. 3 and 4). If the "incident" buttons of more than one of the machines are pressed simultaneously, this queueing device causes the recorders concerned to read out in sequence. Another feature of this installation is a time switch which causes all the accumulated totals to be read out at the end of each shift, leaving the setting of the order number or fault number undisturbed. The time switch also automatically changes the shift number, which is included in the recorded data.

Both a card punch and a tape punch are used for reading out results (Fig. 5). These are in a room adjacent to the accountants office, and are connected electrically to the performance recorders and queueing device, which are in the production department. Such an installation has many advantages. Hand-written records are eliminated, accurate and detailed statistics for the utilisation of machines are quickly available, and time allocations for costing and wages are provided automatically.

A single performance recorder, for use with perforated tape only, can be installed for a few hundred pounds. Multiple equipment suitable for recording data from as many as twenty-five machines shows a substantial saving per machine, even when the additional feature of recording on punched cards as well as on tape is included.

Standards Officers' Meeting in London

THE impact of the proposed European free-trade area on the preparation of industrial standards and on the work of the men who use these standards was underlined by MR. P. D. CANNING, of the Plessey Company, at the third annual meeting of standards officers held in London recently. In evolving and applying good industrial standards the United Kingdom "has been able to lead and guide the continent of Europe—particularly through British participation in the work of the I.E.C. (International Electrotechnical Commission)," said Mr. Canning. "We must continue our efforts if we are to educate the Continent up to our standards rather than let our standards drift down to some of theirs," he continued.

Mr. Canning's observations arose from a discussion on "international standardisation" introduced by MR. GORDON WESTON, B.S.I.'s Technical Director, in which he referred to the growth of other national standards-making bodies whose specifications often had the authority of government backing. In the interests of Britain's export trade it was valuable when international recommendations were being considered to have a good British Standard already in existence, said Mr. Weston; in a number of instances a British Standard had formed the basis for international specifications.

Discussing some of the difficulties of international co-ordination of standards, Mr. Weston referred to the differences in terminology among the English-speaking countries, and to efforts now being made towards greater uniformity between the Commonwealth countries and the United States in such spheres as acoustics, plastics, rubber and nuclear energy. Another difficulty was the inch-metric problem; in some standards, at least, it would be necessary to maintain both inch and metric series.

With reference to screw-threads, MR. C. H. GUBBINS (Wolf Electric Tools) said that in view of Britain's trade with the Continent it would be better for some companies if they were to go over to the metric system rather than that they should adopt the unified thread. Mr. Weston reported that at a recent international standards meeting in Lisbon the unified thread had been agreed for adoption in international standards as the only inch alternative to the metric series. The proposal had been supported by a number of Continental countries, including the Netherlands, Sweden and Finland.

200 Delegates at Church House

This year's meeting of engineers and others responsible for applying standards on the factory floor was the third of such conferences and was far bigger than the two previous gatherings. There were nearly 200 present from manufacturing concerns in all parts of the country, from the nationalised industries and government departments. A special welcome was extended to representatives from five technical colleges. The meeting, organised jointly by the Institution of Production Engineers and the British Standards Institution, was held at Church House, Westminster, under the chairmanship of MR. H. STAFFORD of United Steel Companies.

An important item on the agenda was concerned with stimulating interest in "the three S's—standardisation, simplification, specialisation. MR. H. A. R. BINNEY, introducing this subject, referred to the series of successful meetings held last winter under the leadership of PROF. H. W. MARTIN, the American authority on standards engineering. "Variety," commented Mr. Binney, "is regarded as the spice of life, but to have, for example, several different kinds of sockets for electrical-connections is not real variety. We need to speak of the elimination of unnecessary diversity rather than reduction of variety," he suggested.

Mr. Binney referred to the provision of training courses for standards officers at technical colleges and universities. Two such courses had been held as part of Prof. Martin's programme—at the Regent Street Polytechnic and the Manchester College of Technology. Further courses were planned by these and other colleges, and B.S.I. was keeping in close touch with the Ministry of Education. An international seminar on the three S's is being held in Holland from July 15th to August 17th. From the discussion which followed it

became apparent that the technical colleges required guidance from industry itself on the kind of courses required, both at the technical and management levels.

Mr. Stafford commented from the chair that the principles of standardisation were the same whether electrical equipment or office stationery was involved. He believed that a curriculum in standards technique could be drawn up for engineering colleges and he said that as standards officers they should be prepared to provide lecturers.

Suggestions on Coding

Progress with work on coding was reviewed by MR. A. PARRISH (Imperial Chemical Industries). Since the last conference a special panel had considered three main problems :—

(1) *Code Numbers of Products.*—The panel thought it impracticable to evolve a code which would identify every item used by British industry ; the most practicable method would be to use British Standards as the basis of a national system of coding, leaving individual firms to prepare their own detailed codes.

(2) *Numbering of British Standards.*—The panel considered whether any new system of numbering standards might help in coding by supplying an element of significance in the numbering system ; it was decided that there was no justification for altering the present system.

(3) *Indexing the Content of British Standards.*—The panel believed that an attempt should be made to index the main features of British Standards, features not readily traceable and which were of wider application than the particular standard in which they occurred. The panel thought that a card index system for this type of information could be made available to B.S.I. subscribers.

Summary Sheets

The 1955 standards officers' conference had recommended the preparation of summary sheets as supplements to British Standards. The first of these—extracted from B.S.1768—had been issued, and others extracted from B.S.1981 and B.S.1083 would be published shortly, it was reported by Mr. Weston. MR. R. E. MILLS (A. V. Roe and Company) said the production of sheets should be drastically speeded up to bring in, among others, bolts and nuts, washers, limits and fits, splines and serrations. The chairman intervened in the discussion to explain that summary sheets were designed more for the smaller firm which did not have its own standards department, and should be regarded as an additional reference to, not as a replacement of, British Standards.

The Role of the Standards Department

" The role of national and company standards " was discussed in two papers, in the first of which MR. S. T. ROBINSON, standards engineer of S. Smith and Sons (England) discussed the part they played in a large producing organisation. He regarded his standards department as being primarily an information service. In the larger organisation—particularly where there were a number of different factories, some possibly abroad—it was often difficult to let the left hand know what the right hand was doing. The standards department was useful in spreading information and putting people into touch with each other. The speaker listed three objectives for the standards department : (1) saving time—by presenting information " on a plate " ; (2) concentrating demand—through limiting the range of purchasing departments ; (3) preserving quality—by keeping up-to-date records of new developments in standards and other fields. He said that the job of the standards officer was to obtain information, interpret that information and present it complete to the designer. " We have to make standards available to people in a digestible form. The standards officer does a job which other people have no time to do."

In the second paper, MR. E. L. DELMAR-MORGAN, of the Shell Petroleum Company, spoke on " standardisation for large users." The advantages of simplification and standardisation were recognised by the big process industries as a way to cut down expenses. Shell had begun many years ago to economise in materials, to prevent materials becoming redundant and deal with stores and stockrooms which would otherwise have been piled high. " If this early effort had not been made Shell's buying departments would be double or quadruple their present size," said Mr. Delmar-Morgan. He went on to explain how they compiled a huge catalogue of every piece of equipment used by Shell in all parts of the world. Such items were easily identifiable to a shipping clerk in Singapore as well as to buying clerks in London. " Cataloguing is the heart of standardisation," he said. " The basic principle must be : one item, one number, many end-users."

Aluminium Forging Press with Side Rams.

HARVEY ALUMINIUM is now in full production on a 4,000 ton hydraulic forging press with side rams. In operation at the Torrance, California, plant, the newly installed press makes it possible for Harvey to produce complex aluminium shapes and parts incorporating under-cuts or back-drafts. The press is of the down-stroke column type design and has an overall height of 43 ft. The size of the press bed between positive stops is 70 in. front to back and 90 in. left to right. Daylight capacity ranges from 45 in. minimum to 90 in. maximum. The main ram can apply 4,000 tons of pressure, and each of the opposed side rams can exert a pressure of 2,000 tons.

Split dies can be attached to the side cylinders while the vertical ram performs a forging or piercing operation. Conversely, a conventional set of dies can be installed on the main ram and the press bed and piercing operations can be done with the side rams. Typical of the aluminium shapes that can be forged on this new press is a valve body with 12 in. diameter flanges at each end, an 8 in. diameter body between the flanges, and a 5 in. diameter hole punched in the centre : parts with unsymmetrical bosses can also be forged.

Change of Address

THE office of the Blackman Export Co. Ltd., a subsidiary of Keith Blackman, Ltd., has been moved from 23, Queen Square, London, W.C.1, to the parent company's head office at Mill Mead Road, London, N.17. At the same time Keith Blackman, Ltd., opened a London area sales office at the Queen Square address vacated by Blackman Export Co. Ltd.

Occurrence of the Beta-Manganese Structure in Transition Metal Alloys and Some Observations on Chi-Phase Equilibria

By H. J. Goldschmidt, D.Sc., F.Inst.P.

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The complex structures of manganese are of great theoretical interest, as prototypes for certain transition metal compounds occurring in alloy steels. The phase-assemblies of Fe-Cr-W-C alloys reveal a new intermetallic compound, possessing the β-manganese structure. The phase is stable at high temperatures, and is associated with the " chi-phase " of α-manganese structure. Some characteristics of both compounds and their equilibria with ferrite, austenite and sigma-phase are here described. The chi-phase dissolves appreciable carbon and can be considered as both a " carbide " and a primary carbon-solvent.

AMONGST pure transition metals, manganese is singular in several respects: firstly, it possesses its complex allotropic series of crystal structures —two of which, α- and β-manganese, are highly complicated—amidst metals in the periodic table of normal structures. Secondly, the key position of manganese in ferrous metallurgy, intermediate to the iron and chromium group elements, which are mutually compound-forming (*viz.*, σ- and ξ-phases), makes it in principle possible that these allotropic structures will form prototypes to binary or ternary compounds occurring in systems not themselves containing manganese. The converse case of the σ-phase (as a hitherto " binary " compound between the elements surrounding manganese, Fe-Cr, Fe-V, etc.), occurring in a pure element, namely β-uranium, is now well-known, and it is significant that in both cases the parent-structure to σ is the body-centred cube. Finally, manganese occupies a boundary position between strong and weak carbide-forming elements, a point which will become important in further considerations below.

In the course of X-ray investigations on transition-metal systems carried out during the past several years, a new intermetallic compound was discovered, isomorphous with β-manganese, and believed to be of interest from both the fundamental and the practical metallographic aspects. The phase occurred pure over an appreciable composition range in the Fe-Cr-W-C system, a representative composition being $Fe_{10}Cr_9W_2C$. The phase was first observed by the author in early 1954, but he has deferred reporting it while attempting to define its composition and nature more accurately, as outlined below. The compound is stable only at high temperatures close to the melting point, but can be retained by severe quenching.

The object of this note is to report and discuss this and some related results in their broader aspects. The occurrence of a similar isomorph has recently been reported by Knox[1] in electrolytic extracts from a tungsten die steel and from burnt high speed steels, in most gratifying confirmation of the present result.

The χ-Phase

Andrews[2] was the first to observe a compound of the α-manganese structure (χ-phase) in electrolytic extracts from alloy steels. This has now been identified as essentially a ternary Fe-Cr-Mo compound[3,4]; it also occurs in the Fe-Cr-W system.[5] A number of further isomorphous replacements in χ-phase have been reported,[6] notably Beck's rhenium-base compounds,[7] and we ought now to regard the phase as one of major importance in alloy-steel and other transition-metal systems. In the present investigations, the χ-phase was re-affirmed as a common one, with wide isomorphous flexibility, as will be shown below.

The crystal structure of the χ-phase has been determined by Kasper,[4] who confirmed its agreement with that of α-manganese, found by Bradley and Thewlis[8] (cubic, space group T_d^3-$I\bar{4}3m$, 58 atoms per unit cell, $a_0 = 8{\cdot}912$ kX).* The present χ-spacings vary considerably, *viz.*, from 8·84 to 8·94 kX.

The Phase of β-Manganese Structure

The principal new point is the occurrence of the β-manganese isomorph, in simulation of the allotropic relations in manganese-metal. The phase is stable only above temperatures of about 1,350° C.—in manganese, the α-β transformation point is 742° C.—but it can be retained by water-quenching from 1,400° C. It occurred pure at a composition: 40·3% Fe, 35·2% W, 23·6% Cr, 0·9% C (by weight), the same alloy transforming to χ-phase at lower temperatures. The new phase will here be denoted "π."

There is one important difference from the manganese-analogy, in that the decomposition product of π is not necessarily single-phase χ; a reaction:

$$\underset{\beta\text{-Mn structure}}{\pi} \longrightarrow \underset{\alpha\text{-Mn structure}}{\chi} + \underset{\text{b.c.c. ferrite}}{\alpha\text{-Fe}}$$

has been generally observed. The ferrite thus produced is of greatly expanded spacing compared with pure iron, owing to tungsten solid solution.

The alloys used in the present study covered parts of

* There are four types of atom in α-manganese, occupying (in Bradley and Thewlis' denotation[8]), the 2 X, 8 A, 24 D_1 and 24 D_2 sites, distinguished by different interatomic distances and environment. In χ-phase, $Fe_6Cr_{18}Mo_{10}$, the X and A sites are occupied by molybdenum atoms, D_1 and D_2 being shared by iron and chromium atoms (Kasper[4]); this sharing is partly ascribed to lack of equilibrium, and Kasper presumed that true equilibrium corresponds to complete ordering of chromium into D_1 positions (i.e., D_1 = 12 Fe, 12 Cr; D_2 = 24 Fe, 0 Cr). As shown below, the above formula is by no means rigid, and a considerable homogeneity range exists with varying Fe/Cr/Mo or Fe/Cr/W atom ratio.

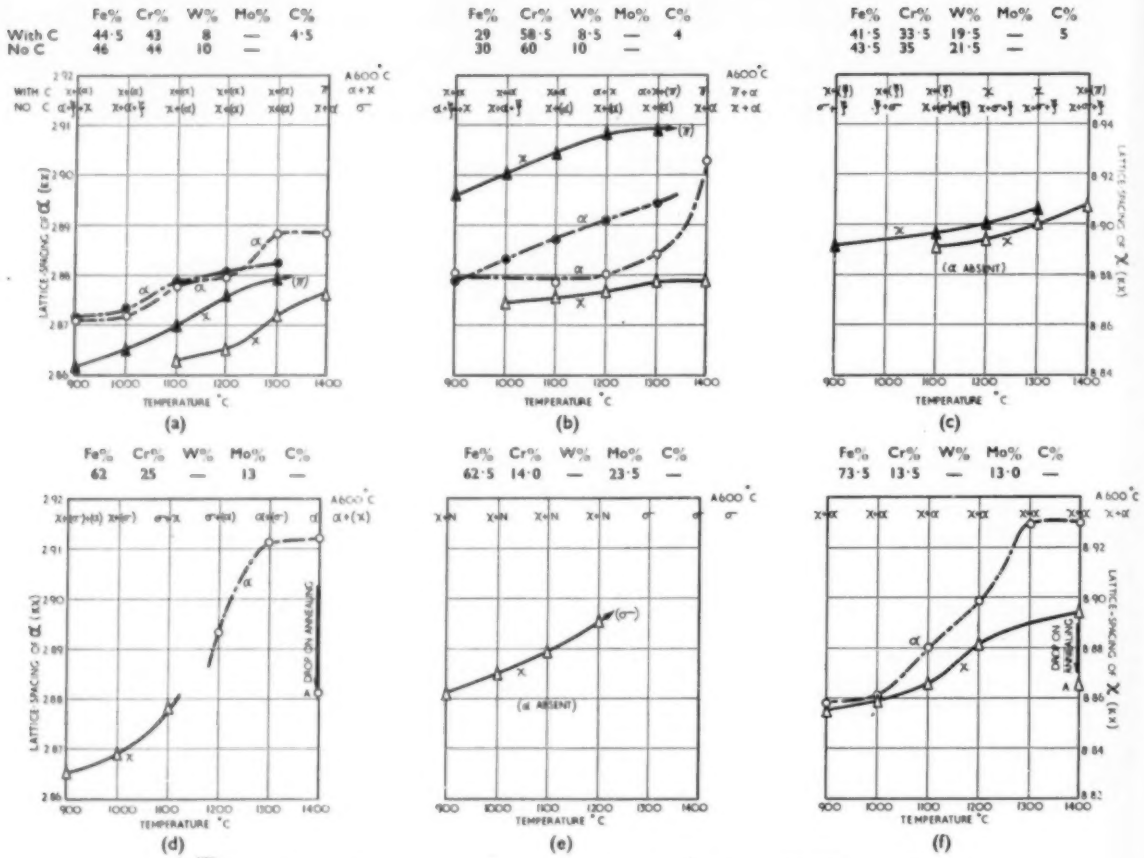
Fe% Cr% W% Mo% C%
With C 44·5 43 8 — 4·5
No C 46 44 10 —
Fe% Cr% W% Mo% C%
29 58·5 8·5 — 4
30 60 10 —
Fe% Cr% W% Mo% C%
41·5 33·5 19·5 — 5
43·5 35 21·5 —
A 600°C
WITH C
NO C
LATTICE SPACING OF α (Å)
LATTICE SPACING OF χ (Å)
TEMPERATURE °C
(α ABSENT)
(a)
(b)
(c)
Fe% Cr% W% Mo% C%
62 25 — 13 —
Fe% Cr% W% Mo% C%
62·5 14·0 — 23·5 —
Fe% Cr% W% Mo% C%
73·5 13·5 — 13·0 —
DROP ON ANNEALING
(d)
(e)
(f)
KEY :-
χ PHASE IN ALLOY WITH CARBON
χ PHASE IN ALLOY WITHOUT CARBON
α (FERRITE) IN ALLOY WITH CARBON
α (FERRITE) IN ALLOY WITHOUT CARBON
A ALLOY ANNEALED 600°C AFTER QUENCHING 1100 °C
( ) SMALL AMOUNT OF PHASE

Fig. 1.—Typical phase-transformations and changes in lattice dimensions with quenching temperature in Fe-Cr-W, Fe-Cr-W-C and Fe-Cr-Mo alloys, involving χ (α - Mn) and π (β - Mn) phases. In the top three graphs equivalent alloys with and without carbon are compared. The compositions are given in atomic percentages.

the Fe-Cr-Mo, Fe-Cr-W and Fe-Cr-W-C systems; they were a number of experimental casts and small argon-arc furnace melts, as well as sinter-compacts prepared by powder-metallurgy methods, some use being made also of samples available from a previous investigation.[9] The compositions ranged between approximately 8 and 24 at.-% Mo or W, the carbon-content in the quaternary system being at the 5 at. - % level (in weight % : 20–35 Mo, 24–47 W, ≈ 0·8–0·9 C). The alloys were chosen such that a direct comparison between carbon-free and carbon-bearing compositions, of the same metal-atom content, was possible. The heat-treatments given consisted of water-quenching in vacuum from a series of temperatures between 900 and 1,400° C. (some higher, as described below) after varying times at temperature, as well as long-time annealing at 600° C.; examination in the as-cast state was also carried out in a number of cases.

Conditions of Formation and Retention of π-Phase

Typical phase-sequences leading up to the π-phase are shown in Table I. Lattice-spacing changes of α and χ are shown in Fig. 1, together with some additional constitutions.

TABLE I.—SOME PHASE CONSTITUTIONS CULMINATING IN THE π-PHASE.

Heat Treatment	Constitution		
	Alloy I*	Alloy II*	Alloy III*
900° C. 1 hr., W.Q.	χ + α	χ + (α)	η + α
1,000° C. 1 hr., W.Q.	χ + α	χ + (α)	η + α
1,100° C. 1 hr., W.Q.	α + χ	χ + (α)	η + γ
1,200° C. 1 hr., W.Q.	α + χ	χ + (α)	γ + η
1,300° C. 1 hr., W.Q.	α + χ + (π)	χ + α	γ + η
1,400° C. 1 hr., W.Q.	π	π	γ + π + (η)
1,400° C. 1 hr., W.Q., 600° C. 100 hr.	π + α + χ	α + χ	α + η + (π)
1,400° C. 1 hr., W.Q., 600° C. 2,000 hr. (low temperature equilibrium)	χ + α	χ + α	α + η

* Composition			Fe	Cr	W	C
	Alloy I	Wt.-%	26·4	48·4	24·4	0·80
		At.-%	29·6	58·5	8·5	4·4
	Alloy II	Wt.-%	40·3	35·2	23·6	0·87
		At.-%	44·5	4·3	0·8	4·5
	Alloy III	Wt.-%	65·6	7·3	26·1	0·95
		At.-%	76·5	9·2	9·2	5·0

α Ferrite or martensite.
γ Austenite.
η η-Carbide.
χ α-Manganese structure.
π β-Manganese structure.
( ) Small amount.

Although π-phase may be considered as a high temperature form to χ, each structure possesses its own solubility range, as implied by the above reaction $\pi \longrightarrow \chi + \alpha$. (The similarity in this respect to austenite and ferrite in steels may be noted). Furthermore, it was found that cold-work could also produce this reaction: from π present as quenched, it was possible by cold-work such as hammering to produce $(\pi + \chi + \alpha)$ or $(\chi + \alpha)$ assemblies in varying phase-proportions. Variations in quenching temperature and rate were able to result in similar variations of $\pi/(\chi + \alpha)$ ratio.

The resemblance to the $\gamma \rightleftharpoons \alpha$ relation in steels suggests comparing the reaction:

$$\pi \longrightarrow \alpha + \chi \qquad (1)$$

with the eutectoid reaction:

$$\gamma \longrightarrow \alpha + \text{carbide} \qquad (2)$$

As austenite can be variably retained on quenching from the γ-field, so can the phase of β-manganese structure on quenching from a higher temperature (*viz.*, in the region of the solidus), and broadly similar factors can cause their decomposition. The role of χ as a "carbide" leads to another point to be discussed in a later section.

The exact nature of reaction (1) and the conditions controlling π-retention are not yet known, but certain qualitative trends can be indicated. For example, the quenching temperature favouring π-retention can be too high, in which case a reversion to χ occurs. Some sequences observed are as follows:

ALLOY I (TABLE I)

	π	χ	α
Below 1,200° C.	—	L/M	L/M
Q 1,200° C.	—	L/M	L/M
Q 1,300° C.	S	L	M
Q 1,350° C.	S/M	L	S
Q 1,400° C.	100%	—	—
Q 1,450° C.	M	M	S
Q 1,500° C.	—	L	S

ALLOY II (TABLE I)

	π	χ	α
Below 1,360° C.	—	L	M
Q 1,360° C.	—	L	M
Q 1,380° C.	L	S/M	—
Q 1,400° C.	100%	—	—
Q 1,430° C.	S	L/M	M
Q 1,460° C.	—	L	M

Q Quenched from.
S Small amount.
M Medium amount.
L Large amount.
100% Pure (as far as visible).

It would suggest the possibility of π forming peritectically and being stable over a narrow high-temperature range; depending on the rate of traversing the interval between the liquidus and solidus, and on the initial temperature attained within it, coring would occur, and the reaction: Liquid $\longrightarrow \pi \longrightarrow \chi + \alpha$ proceed to varying extent, so that, on quenching, π-formation may become inhibited. Fig. 2 shows diagrammatic high-temperature equilibria suggested as possible alternatives.

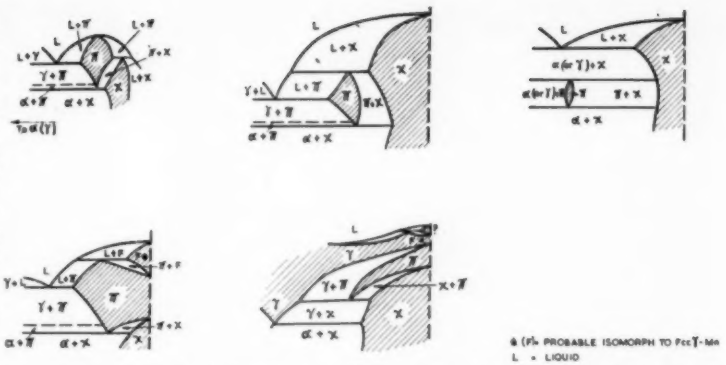

Fig. 2.—Suggested alternative equilibria near melting point for π and χ phases coexisting with primary ferrite and/or austenite. (Schematic).

Fig. 3 shows typical photomicrographs of a quenched alloy (larger samples than those of Table I were used here), containing $\pi - \chi - \alpha$ three-phase assemblies, as verified by X-ray examination. The spherulites here correspond to ferrite, and the background to χ- and π-phase. These samples had partially melted to form globules; at one place (top right photomicrograph) there are pronounced dendrites grown adjoining the sample surface: they probably correspond to the π-phase which solidifies first.

Structure of π-Phase

The crystal-structure of β-manganese is known from the work of Preston,[10] Bradley,[11] and Westgren and Phragmen,[12] and details are shown in Table II. The lattice-spacing of the new π-phase varies with composition, the values ranging from $a_0 = 6{\cdot}27$ to $6{\cdot}39$ kX, as against $6{\cdot}29$ kX for β-manganese (see next section).

In Preston's β-manganese structure there exist two types of manganese atom, comprising 12 and 8, respectively, of the 20 per unit cell, characterised by the interatomic distances and positions shown. These two types will differ in their electronic states, and in the π-phase

TABLE II.—STRUCTURE OF β-MANGANESE.

Symmetry: Cubic. *Space Group*: O^7-$P4_132$ or O^8-$P4_332$.
Lattice Spacing: $a_0 = 6{\cdot}289$kX. *No. of Atoms per Unit Cell*: 20.
Atomic Positions: Two kinds of manganese atom, 12 Mn_A and 8 Mn_B of co-ordinates:

Mn_A

$\frac{3}{4} - u, u, \frac{1}{4}$; $\frac{1}{4} - u, \frac{1}{2} - u, \frac{3}{4}$; $u + \frac{1}{4}, u + \frac{1}{2}, \frac{1}{4}$; $u + \frac{3}{4}, u, \frac{3}{4}$

$\frac{1}{4}, \frac{3}{4} - u, u$; $\frac{3}{4}, \frac{1}{4} - u, \frac{1}{2} - u$; $\frac{1}{4}, u + \frac{1}{4}, u + \frac{1}{2}$; $\frac{3}{4}, u + \frac{3}{4}, \bar{u}$

$u, \frac{1}{4}, \frac{3}{4} - u$; $\frac{1}{2} - u, \frac{3}{4}, \frac{1}{4} - u$; $u + \frac{1}{2}, \frac{1}{4}, u + \frac{1}{4}$; $\bar{u}, \frac{3}{4}, u + \frac{3}{4}$

$u = 0{\cdot}206$

Mn_B

v, v, v ; $v + \frac{1}{2}, \frac{1}{2} - v, \bar{v}$; $v + \frac{3}{4}, \frac{1}{2} - v, \frac{1}{4} - v$; $\frac{1}{2} - v, \bar{v}, v + \frac{1}{2}$

$\frac{3}{4} - v, \frac{3}{4} - v, \frac{3}{4} - v$; $v + \frac{1}{2}, \frac{1}{2} - v, v + \frac{3}{4}$; $\frac{1}{2} - v, v + \frac{3}{4}, v + \frac{1}{4}$; $v + \frac{3}{4}, v + \frac{1}{4}, \frac{1}{2} - v$

$v = 0{\cdot}061$

*Interatomic Distances (kX)**

Neighbours to Mn_A atoms	Neighbours to Mn_B atoms
2 at 2·530	3 at 2·365
2 at 2·615	3 at 2·530
4 at 2·659	3 at 2·671
2 at 2·671	3 at 2·675
2 at 2·675	

* Each atom has 12 neighbours at slightly varying distances, giving a modified type of close packing. The environment of Mn_A atoms forms a regular icosahedron, that of Mn_B atoms approaches cubic close-packing.

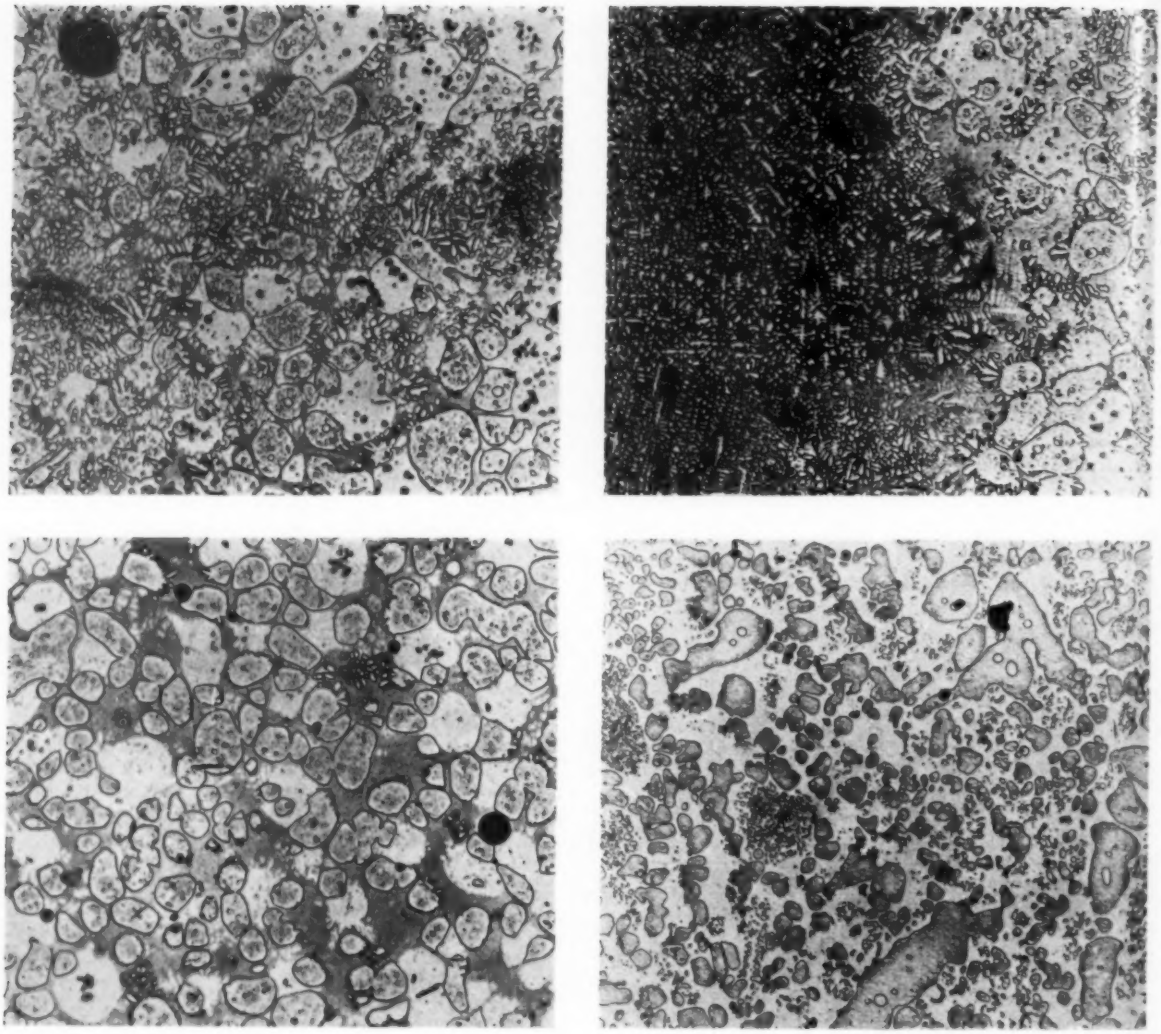

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Fig. 3.—Photomicrographs showing typical ($\pi+\chi+\alpha$) phase-assemblies. Alloy : 40·3% Fe, 35·2% Cr, 23·6% W, 0·87% C, as water quenched from 1,400° C., but with slight variations in treatment. Top right photomicrograph (exceptional) shows dendrites formed at one corner of a sample. Etched Murakami's reagent. ×250

will offer sites inherently predisposed to occupation by the atoms of different species, in this case, probably the (Cr, W) and the (Cr, Fe) atoms, respectively ; carbon would enter interstitially.

It is significant that π has here been observed pure for Alloys I and II, which atomically may be written $Me_{21}C$ and $Me_{24}C$. With 20 metal atoms per unit-cell, we obtain for Me approximately :

Me = 10 Fe + 8 Cr + 2 W atoms per unit cell in Alloy I

= 6 Fe + 12 Cr + 2 W atoms per unit cell in Alloy II

indicating firstly a considerable iron-chromium replaceability with little or no tungsten variation, and secondly, a correlation with the above two manganese-atom types in β-manganese (Mn_{12} Mn_8), such that in Table II, the more spacious A-sites are preferred by chromium, and the B-sites by iron atoms (though not to the exclusion of chromium), with tungsten entering A ; but the total numbers of 12 and 8 atoms per site-type may well become modified in π as from β-manganese, say to 12 $\pm$ 2 and 8 $\pm$ 2.

Hume-Rothery[13] has found the electron/atom ratio of 3/2 to be characteristic of intermetallic compounds of the β-manganese type of structure (Ag_3Al, Au_3Al, Cu_5Si, $CoZn_3$), the same as for compounds of the body-centred cubic structure. In the case of π-phase, this would certainly suggest regarding it as an electron-compound ; however, the Hume-Rothery rule is difficult to test here, because the effective valency to ascribe to each atom (Fe, Cr, W, C) is in question, and probably variable. A total of 30 valency electrons per unit cell of π will, however, be a helpful assumption to make in any structure-determination.

A determination of the π-structure has here not been attempted, but it is clearly a task of greatest interest, and some further considerations are set out on page 25.

TABLE III.—INTERPLANAR SPACINGS OF π (β-Mn) AND χ (α-Mn) PHASES.

hkl	π d(kX)	Intensity	hkl	χ d(kX)	Intensity
300, 221	2·12	S	321	2·38	M
310	2·01	SM	400	2·22	W
311	1·91	M	330, 411	2·11	S
321	1·70	MW	332	1·90	M
330, 411	1·49	WM	422	1·82	M
420	$1·42_5$	W	431, 510	1·75	MW
421	1·38	W	600, 442	$1·48_4$	MW
332	1·34	W	611	$1·44_5$	M
431, 510	$1·24_3$	S	622	$1·34_5$	W
333, 511	$1·22_0$	W	444	$1·28_7$	MW
432, 520	$1·17_8$	S	550, 710, 543	$1·26_5$	M
531	$1·07_2$	S	721, 552, 633	$1·21_2$	S
446, 600	$1·06_3$	M	642	$1·90_9$	M
610	$1·04_5$	M	732, 651	$1·13_8$	MW
			811, 741, 554	$1·09_6$	MW
			822, 660	$1·05_1$	M

S, Strong; M, Medium; W, Weak.
(Co K_α radiation)

The interplanar spacings for π- and χ-phase are shown in Table III.

Lattice-Spacings of π-Phase

The lattice-spacings of π-phase depend on alloy-composition, and, for a given alloy, on heat-treatment, which also determines the nature and amount of any other phases associated with π in the assembly. Typical values observed are as follows:

	Alloy (see Table I)	Lattice Spacing of π(kX)	Phase Coexisting	
Constant heat-treatment—	I	6·361	(π pure)	
	II	6·275	(π pure)	
W.Q., 1,400° C.	III	6·290	γ and small η	
Constant alloy composition	II	6·275	(π pure)	χ increasing
		6·352	χ small	
		6·390	χ small to medium.	

This compares with 6·289 kX for β-manganese, and with 6·382 kX in Kuo's alloy[1] (die steel containing 1·47% C, 8·22% W), where the phase was a subsidiary within an austenite-martensite matrix.

The phase thus possesses a considerable homogeneity field, varying in extent with temperature; the lattice-expansion of π runs parallel with the increasing amount of χ-phase present, indicating a recession of the π-phase boundary towards tungsten-richer compositions, as χ precipitates. Furthermore, amongst different alloys the larger spacings of π-phase are accompanied by the larger spacings of the χ-phase in those cases where the latter precedes π-formation at lower temperatures.

The fact that Alloy III is the richest in iron is consistent with the π-spacing being low (6·29 kX, similar to β-manganese proper); but π here coexists with austenite and η carbide, which may have rendered the spacing greater than it would have been for pure π. (See also link between this alloy and high-speed steels referred to below.) It is of interest to note that π can act as parent-phase to either χ or η, and that, in the process of this precipitation, π expands; this is a similar but reverse case to the well-known contraction of austenite during the precipitation of secondary phases. Kuo's relatively large spacing value (6·382 kX) would reflect a composition richer in tungsten than for the present π-phases, except in the last instance above, which attained the same order.

One textural feature distinguishing χ- from π-phase is a permanent difference in crystal-size; on X-ray powder-photographs the finer crystal size of π sometimes reveals itself clearly by "spotty" χ lines amongst the uniform ones of π.

χ—π-Phase Equilibria

Lattice Dimensions of χ and Ferrite, and Effect of Carbon on π-Formation

Carbon plays an integral part in stabilising the π-phase. A detailed search for the carbon-free isomorph in the Fe-Cr-W and Fe-Cr-Mo systems has not been able to produce it, even by severe quenches and for compositions equivalent to those which, with carbon, had yielded the phase. Typical comparisons of such phase assemblies in "carbon/no-carbon" alloy pairs are shown in Fig. 1. This failure to produce carbon-free π by quenching does not, of course, disprove its existence at high temperature, as, like carbon-free γ-iron, it may be unquenchable.

Alongside the constitutions, Fig. 1 shows the associated lattice-spacing curves for phases α and χ; the increase in spacing culminates in π-formation, where shown. These lattice expansions with quenching temperature are due to solution of tungsten or molybdenum in the lattice, whilst the increases in spacing of Fe-Cr-W-C alloys, as against Fe-Cr-W alloys, are due to solution of carbon in the lattice.

One important feature arising from these spacing-changes is a marked movement of the α and χ single-phase boundaries with temperature; this solubility-change would imply age-hardenability, in that, on ageing the as-quenched alloy, χ-phase would nucleate from α. This effect manifests itself conversely by the α-contraction observed on annealing (see arrows, Fig. 1). In the carbon-bearing alloys, the solute increase in α and χ then ceases with π-formation at highest temperatures.

Although the χ- and π-phases are intermetallic compounds, and as such brittle, they are structurally characteristic of a pure metal—manganese—and, in certain respects, they behave indeed like primary solid solutions in steels (austenite, ferrite), such as in their variable solution-fields and ability to act as matrix phases for secondary precipitants; it may well be asked whether their brittleness may not be less than in normal intermetallic compounds (σ, ξ, etc.), and whether they may not possess a strong coherency with true α- and γ-matrix crystals.

The occurrence of the χ- and π-structures and their interplay with ferrite, austenite, σ and other phases will further contribute to (and complicate) the precipitation effects already implied by the above solubility variation, and possibly to high-temperature creep resistance, if we apply the (now well supported) thesis that a complexity of structures tending to precipitate over a temperature range would promote this property.

χ-Phase Assemblies in Carbon-Free Alloys

In the present work the χ-phase has been confirmed in both the systems Fe-Cr-Mo (where it is known[2, 3, 4]) and in Fe-Cr-W (where it is believed to be new[5]). The location of the χ-phase field is fully analogous in both systems, namely intermediate to the σ (Fe-Cr base) and ξ ($Fe_3(Mo, W)_2$ base) fields, as is indicated in Figs. 4 and

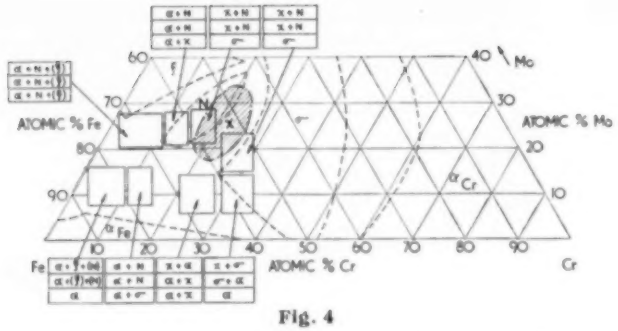

Fig. 4

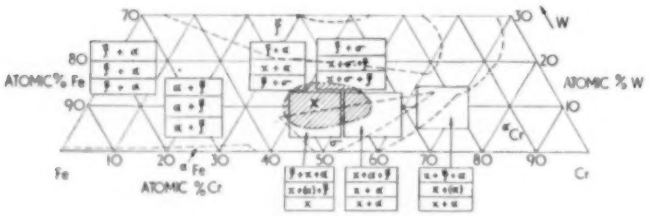

Fig. 5

Figs. 4 and 5.—Representative phase-constitutions of Fe-Cr-Mo and Fe-Cr-W alloys as quenched from high temperatures. Phases in framed blocks correspond to 1,000, 1,200 and 1,400° C. quenches, reading from top to bottom. (Superimposed on outline of 600° C. diagram derived previously). The approximate position of the present χ-phase field is shown shaded.

5 ; this means, however, that, in terms of composition, there is a considerable difference between χ (Fe-Cr-Mo) and χ (Fe-Cr-W). The phase becomes stable when, to σ-bearing Fe-Cr alloys, about 10 at.% W is added, whilst the addition of about 17 at.% Mo is required with a simultaneous decrease in Cr/Fe ratio ; typical stoichiometric compositions for pure χ (calculated to the total of 58 atoms per unit cell) are : Fe_{28} Cr_{23} W_7 as against Fe_{36} Cr_{12} Mo_{10} ; these precise formulae should, however, not be stressed because, as shown by the spacing changes, the phase possesses appreciable ternary homogeneity fields in both cases. A quantitative outline of χ phase-boundaries in temperature/composition space cannot be given at this stage.

The carbon-free χ-phase forms a series of assemblies with the σ, ξ and (in the case of molybdenum) " *N* " phases, and with the primary ferrite and austenite, to which, with carbon, the η-carbide must be added. Its stability region at high temperatures in Fe-Cr-Mo partially overlaps with that of the *N*-phase,[5] and can, with temperature, be surmounted by σ ; an example is shown in Fig. 1 *c*, where the transformation : (χ + *N*) (1,200° C.) ⟶ σ (1,300° C.) has occurred. The presence or absence of χ sensitively depends on temperature and heat-treatment, and the complexity-effect again enters, so that, as with the carbon-containing alloys above, it would entail the condition of successive nucleations, relevant to creep-resistance.

σ-Phase in the Fe-Cr-Mo system changes from a low to a high-temperature phase, on passing from the Fe-Cr to the Fe-Mo binary side, and the intervention of χ as intermediary compound is of particular interest, because in different alloys, σ can form similar series of (χ, α, *N*) assemblies and, depending on Cr/Mo ratio be stable either at higher or at lower temperatures than these. $\chi \rightleftharpoons \sigma$ transitions following this behaviour have here been observed in various alloys.

This complex set of competitive structures occurring for only minor free energy changes implies that metastable equilibria can readily form and persist. One manifestation is a change in constitution with time held at temperature before quenching, as in the following two examples :

Alloy (at.-%)	Time before Quenching from 1,200° C. and Phases Formed	As-Cast Constitution
(A) 62/21/17 (Fe/Cr/Mo)	5 minutes ⟶ χ + α 2 hours ⟶ σ + α + (χ) 100 hours ⟶ σ + α	χ + γ
(B) 48/40/12 (Fe/Cr/W)	5 minutes ⟶ σ 100 hours ⟶ χ + α	σ

This time progression is paralleled by one with temperature for constant time, as shown for instance by Alloy A above, which contained χ + α as quenched from 1,400°C and pure σ as quenched from 1,450° C. (time 5 minutes in both cases).

A similar phase sequence, but this time with changing composition and constant heat-treatment (quench 1,400° C. after 5 minutes) was illustrated by the following experiment. Starting with Alloy B above, and adding 4 and 7 at.-% W to the small ingot by argon-arc melting, we obtained :

48/40/12 (Fe/Cr/W) ⟶ χ + α
46/38/16 (Fe/Cr/W) ⟶ χ + α
44·5/36·5/19 (Fe/Cr/W) ⟶ σ

Some Further Observations on χ (Fe-Cr-Mo) and χ (Fe-Cr-W) Assemblies

Various additional features of χ-phase assemblies are here worth noting.

Fe-Cr-Mo.—(1) The α-phase (ferrite) expansion with increasing quenching temperature (Fig. 1) has its counterpart in the sharp contraction on tempering the same alloy at 600° C. ; it reflects first solution, then rejection of the molybdenum-bearing phase. (2) Both the χ- and the α-phases expand with increasing quenching temperature, showing simultaneous molybdenum-solution ; this is accompanied by a gain in amount of α from χ, indicating

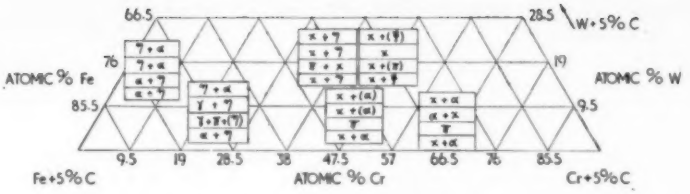

Fig. 6.—Representative phase-constitutions of Fe-Cr-W-C alloys at 5 at. % carbon level. Phases in framed blocks correspond to 1,000, 1,200 and 1,400° C. quenches, and to 600° C. anneals, reading from top to bottom.

that the α-region encroaches, as the χ-boundary recedes. (3) Between 1,300 and 1,400° C., the expansion of α becomes retarded or even reversed (*c.f.* Fig. 1), indicative of the formation of a molybdenum-richer phase, as under (1); this can be either χ, ξ, *N* or σ. (4) On adding chromium to ξ (Fe_7Mo_6), this phase is displaced successively by *N*, χ and σ, involving, with increasing chromium, a sequence of $(\alpha + N) \longrightarrow (\alpha + \chi) \longrightarrow (\chi + N) \longrightarrow (\sigma + \chi)/(\sigma + N)$ equilibria (see Fig. 4). Depending on preceding heat treatment, there is, however, an appreciable compositional overlap of phases, whether stable or metastable. (5) Primary austenite is able to co-exist with χ-phase, as it is with η-carbide when the latter displaces χ. This is discussed later in the section on transition to high-speed steels.

Fe-Cr-W.—The χ (Fe-Cr-W) phase was observed in alloys of the following typical compositions (Fe/Cr/W, atomic %): pure in 48/40/12; predominant, but coexisting with α, ξ or σ, in 30/60/10, 46/44/10, 43·5/35/21·5. As in χ (Fe-Cr-Mo), there is a considerable iron ⇌ chromium replaceability, consistent with the finding[4] that iron and chromium are able partly to substitute in the 24 D_1 and 24 D_2 lattice sites of the α-manganese structure. However, there also appears a slight variability in the content of large atoms (tungsten and molybdenum), and structurally this can only be explained either by their substitution for some of the chromium or, if molybdenum and tungsten strictly adhere to the 2X and 8A sites, by defect lattice formation at D_1 and D_2.

Effect of Carbon on Metal Content of χ.—The expansion of the χ-lattice by carbon has already been described (*c.f.* Fig. 1). Comparing the total metal-atom compositions of pure χ (Fe-Cr-W) and χ (Fe-Cr-W-C), we have:

Carbon free: $Fe_{48}Cr_{40}W_{12}$; Fe/Cr = 1·2, Cr/W = 3·3

Carbon bearing: $Fe_{43\cdot5}Cr_{36}W_{20\cdot5}$; Fe/Cr = 1·2, Cr/W = 1·75.

It shows that whilst the Fe/Cr ratio is the same, the presence of interstitial carbon would admit more tungsten, namely an increase from about 7 to 12 tungsten atoms amongst the 58 per unit-cell. The corresponding figure in χ (Fe-Cr-Mo) was 10 molybdenum atoms, at the 2 X and 8 A lattice-points; there seems therefore, a tolerance in accommodating molybdenum (tungsten) or chromium at these sites, likely to differ between the two site-groups, depending on the interstitial carbon present.

χ-Phase in the Fe-Cr-Mo-C System.—The system Fe-Cr-Mo with carbon was not dealt with in the present investigation, except for a few pilot experiments. These showed that, after identical heat-treatment (quench 1,400° C.) a pure Fe-Cr-Mo alloy of constitution: α (large) + σ (small) had, on carbon-addition by arc-melting, become: χ (large) + α (small), i.e., carbon had produced χ, by the reaction:

Ferrite + σ + C ⟶ χ + (lesser) ferrite.

Furthermore carburisation of another, originally (χ + α)-bearing, Fe-Cr-Mo alloy had greatly increased the proportion of χ-phase. It can certainly be concluded that χ (Fe-Cr-Mo) phase is a carbon solvent, similar to χ (Fe-Cr-W).

χ-Phase in other Transition Metal Systems

The more general occurrence of the α-manganese structure in other transition-metal systems not containing manganese should again be noted. In investigations associated with the present one, the author has found χ as a Co-W binary compound, where it exists at a high temperature for a composition CoW. After quenching from 1,350° C., this alloy consisted principally of χ-phase with some σ (again the close χ — σ association occurs!), and the phase is likely to be a prominent high-temperature one in the related cobalt-base and nickel-base ternary systems.[14] Greenfield and Beck[7] have observed χ-phase in the systems Re-Nb, Re-Ta, Re-Mo and Re-W. Together with the σ-, Laves- (and now perhaps π-) phases, the χ-phase should be considered as one of the basic prototype structures in transition-metal systems.

χ and π-Phases as "Carbides"

An important aspect of the χ-phase is the discovery of its solid solubility for carbon. In the binary system Mn-C, according to Vogel and Döring,[15] pure α-manganese is able to dissolve up to 1·3% C (= 6·3 at.-% C) at 740° C., so that an appreciable carbon solubility in χ-phase also may not be surprising. It would appear that the phase assumes the double-role of an austenite-like carbon solvent and of a low-carbon "carbide"

The carbide aspect of χ was brought out in the present work on the Fe-Cr-W-C system which, at a constant-carbon section of 5 at.-% C, shows that, as we substitute iron by chromium, the η-carbide Fe_4W_2C, stable in the Fe-corner, is steadily replaced by the χ-phase.

Some typical η ⟶ χ transitions with iron ⟶ chromium replacement are shown in Fig. 6 for a constant carbon content of about 5 at.-% C and at four temperature levels. Such transitions, observed for three successive tungsten-levels at temperatures above 1,000° C. can be represented by the following assembly sequences:

	(Fe ⟶ Cr)
(Fe)	(1) $\gamma + \eta \longrightarrow \sigma + \chi$
(|)	
(|)	(2) α or $\gamma + \eta \longrightarrow \chi + \eta \longrightarrow \chi$
(↓)	
(W)	(3) $\eta + \xi \longrightarrow \chi + \xi$

χ-phase here assumes fully the part of a carbide, though lower in carbon content than η. The presence of carbon in χ is also implied by its present coexistence with ξ, an intermetallic compound capable of dissolving little or no carbon, which in high-speed steels can be produced by decarburisation of η-carbide. On the other hand, the primary carbon solvent (austenite-like) role of χ is illustrated by the consistent expansion caused by carbon (Fig. 1), starting from the carbon-free χ-phase.

TABLE IV.—ALLOY CONSTITUTIONS TO ILLUSTRATE $\chi(\pi) \longrightarrow \eta$-CARBIDE TRANSITION FOR APPROXIMATELY CONSTANT CARBON LEVEL.

Heat Treatment	Constitution				
	Alloy II* ($\chi - \pi$ Case)	Alloy IV† ($\chi - \pi - \eta$ Case)	Alloy III* ($\gamma - \pi - \eta$ Case)	Commercial 18/4/1 High Speed Steel† ($\gamma - \eta$ Case)	Alloy V† ($\alpha - \eta$ Case)
1,000–1,300° C. (and below) 1 hr., W.Q.	$\chi + (\alpha)$	$\chi + \eta$	γ and $\alpha_M + \eta$	$\gamma + \alpha_M + \eta$	$\alpha + \eta$
1,350° C. 1 hr., W.Q.	$\pi + \chi + (\alpha)$	$\chi + \pi$	$\gamma + \pi + (\eta) + \alpha_M$	$\gamma + \alpha_M + \eta$	—
1,400° C. 1 hr., W.Q.	π	$\pi + \chi$	$\gamma + \pi + (\eta)$	$\gamma + \alpha_M + (\eta)$	$\alpha + \eta$
1,100° C. 1 hr., W.Q. 600° C. 2,000 hr.	$\chi + \alpha$	$\chi + \eta$	$\alpha_F + \eta$	$\alpha_F + \eta$	$\alpha + \eta$

* See Table I for Composition.

† Composition

		Fe	Cr	W	V	C
Alloy IV	Wt.-%	37	18·6	43·5	—	0·8
	At.-%	50	27	18	—	5
Alloy V	Wt.-%	56	0	42·5	—	0·9
	At.-%	77	0	17·5	—	5·5
Commercial 18/4/1 High Speed Steel	Wt.-%	75·1	4	19	1·5	0·8
	At.-%	83	4·8	6·3	1·7	4

α_F Ferrite.
α_M Martensite.
γ Austenite.
η η-Carbide.
χ α-Manganese structure.
π β-Manganese structure.
( ) Small amount.

The α-manganese structure contains sufficiently large lattice holes to accommodate the interstitial carbon-atoms; their exact experimental location by X-rays in the χ-structure would, however, not be possible, as their relative scattering power is too weak to affect intensities; this is a clear case for neutron-diffraction, as applied by Kasper[4] to χ (Fe-Cr-Mo). Stoichiometrically, the above pure χ-" carbide " may, for C = 1, be written as $Me_{18}C \approx Fe_8Cr_{6\cdot3}W_{3\cdot7}C$ ($\eta = Me_6C$); the 58 metal atoms per unit cell would, in this instance, divide as about 26 Fe, 20 Cr, 12 W, with 3 interstitial carbon-atoms.

The π-phase is poorer in carbon than χ, as indicated by the reaction $\pi \longrightarrow \alpha + \chi$ but may nevertheless also be considered as either a primary solvent or a " very low carbide "; the 20 metal atoms per unit cell will hold about 1 carbon atom. The failure, so far, to produce a carbon-free π-phase would support the carbide viewpoint. For β-manganese, Vogel and Döring[15] report a carbon solubility of 0·4 wt.-% C (= 2·5 at.-%), i.e., lower than in α-manganese, which, although the precise figures may be open to doubt, would in principle again fall into line with the carbon-ranking implied by the $\pi \longrightarrow \chi + \alpha$ decomposition.

Transition to High-Speed Steel Group

The above replacement of χ-phase by η-carbide, when chromium is replaced by iron in χ-bearing Fe-Cr-W-C alloys, seems important in linking up with the metallurgy of high-speed and related tungsten-chromium steels, in which η-carbide is prominent.

A comparison is given in Table IV between constitutional sequences observed by X-ray analysis on some experimental Fe-Cr-W-C alloys, again at constant atomic carbon level, and on an 18/4/1 high-speed steel. In terms of constitution, we thus have representatives of five assembly-types, which might be called, a (χ, π) case, a (χ, π, η) case, a (γ, π ,η) case, a (γ, η) case, and an (α, η) case. Alloy III and the high-speed steel have similar constitutions throughout the solid, up to the solidus-liquidus interval, where the simple η-retention of high-speed steel is diverted to π-formation in Alloy III. Thus, as austenite and ferrite coexist with η-carbide in high-speed (type) steel, so they do with π and χ alloys of modified metal-ratios but constant carbon. It therefore seems to arise as a new open factor during metallographic examination of tool-steels that, on varying the transition-metal ratio (Fe/Cr/W, etc.) within the pertinent range of compositions, one should consider, whether or not π- and χ-phase might enter the assembly in addition to, or as compounds alternative to, η-carbide (π on solidification, χ at lower temperatures).

A search by X-rays, during the present investigation, for π and χ in 18/4/1 type high-speed steel itself failed to detect these phases; but this does not exclude their occurrence as a fundamental possibility, e.g., after different treatments. In particular, the retention of π-phase (*a*) in the as-cast condition, (*b*) after any rapid cooling from near-melting temperatures, or (*c*) in segregates, and its removal by further heat-treatment only would seem possible and worth enquiry in specific cases met with in metallographic practice.

Once the π-phase has been preserved by quenching to room-temperature, it is relatively stable and sluggish in decomposing, rather as retained austenite is liable to be. This is shown, for example, by the Fe-Cr-W-C Alloy I (Table I), in which quenching from 1,400° C. retained π: this phase still persisted after annealing at 600° C. for 100 hours, whilst true equilibrium at this temperature correspond to $\chi + \alpha$, as proved by annealing at 600° C. for 2,000 hours. (*N.B.*, another version, incidentally, of the $\pi \longrightarrow \chi + \alpha$ reaction).

Alloys synthesised to the (Fe-Cr-W) compositions shown in Table IV, but without carbon, showed, for the same heat treatments, the replacement of η-carbide by ξ-phase (Fe_3W_2), very similar to the replacement known in decarburised high-speed steels; but, in contrast to η, χ-phase did not so decompose on decarburisation, reaffirming its double-nature as a carbide and as an intermetallic phase.

It may be asked why the $M_{23}C_6$ and M_7C_3 (chromium-base) carbides (κ and λ) did not appear in the present Fe-Cr-W-C alloys. This is because the tungsten content was throughout too high for their occurrence. In

chromium steels with up to approximately 8 at.-% W, we have, of course, observed them frequently.

One may broadly schematise the phase-transitions in the present alloys as follows :

	On Replacement Fe $\rightleftharpoons$ Cr :
Low W, low C :	Transition $\alpha \rightleftharpoons \sigma$
Low W, high C :	Transition $Fe_3C \rightleftharpoons \kappa$ or λ *(with γ or α)
High W, low C :	Transition $\xi \rightleftharpoons \chi$ (with α)
High W, high C :	Transition $\eta \rightleftharpoons \chi$ or *(with γ or α)

* Dependent on heat-treatment.

γ- and δ-Manganese Analogues

Having found in χ and π the structural analogues to α- and β-manganese, it is of interest to enquire whether the systematics cannot be extended, and isomorphs to the other two of the four allotropic forms of manganese (γ- and δ-manganese) be identified with phases prevalent in the same systems.

The answer is simple and in the affirmative, because the face-centred cubic γ-manganese* and the body-centred cubic δ-manganese can readily be identified with austenite and ferrite, and with the "γ- and α-matrix phases" observed in the present assemblies with χ and π. With further modulations in electronic state and atomic size, σ-phase and ξ-phase too can then be brought into equilibrium and be considered as further derivative structures from the body-centred cubic and face-centred cubic parent.

As explained on p. 19, the β-manganese structure is an approach to close packing. The 12-co-ordination involves the somewhat varying distances shown in Table II ; the B-atom environment is that of a distorted face-centred cube, whilst the unusual icosahedral one of the A-atom, may be considered a further distortion, much more drastic, yet still adhering to co-ordination number 12. The two types of environment are shown in Fig. 7. The (111) hexagonal planes of the actual close-packed cubic structure become puckered in the environment of the Mn_B type, and in that of Mn_A type, the pseudo-hexagonal "planes," though severely distorted, can fundamentally still be recognised.

Pseudo-hexagonal sheets are a feature common to the present intermetallic compound structures : they recur for instance in the σ-phase[16] (as alternate layers), and, in different modes, in α-manganese and the "*P*" phase of the Ni-Cr-Mo system.[17] However, in the structures other than that of β-manganese the co-ordination numbers differ from 12, and only in β-manganese (π-phase) is the simpler relation to the face-centred cube maintained.

Indeed, the true face-centred cube is found in γ-manganese (the parent allotrope to β) so that the β-manganese structure can be directly derived by a simple mechanism of short-range atomic displacements. During the austenite $\longrightarrow \pi$ (Fe-Cr-W-C) transformation the same must apply, no long-distance diffusion being necessary (though not excluded) within the face-centred cubic parent structure.

The occurrence of the $\gamma \longrightarrow \beta$ transformation in manganese at 1,190° C. can thus be explained by the manganese atom undergoing an anomaly in its electron configuration, such that the Mn_A and Mn_B type atoms of divided valency in β are produced from the previously single type manganese atom. Similarly, we might say that normal austenite is, under suitable conditions, able to collapse to π-phase through a likewise adjustment in electronic structure.

* Face-centred tetragonal as quenched, but cubic at temperature.

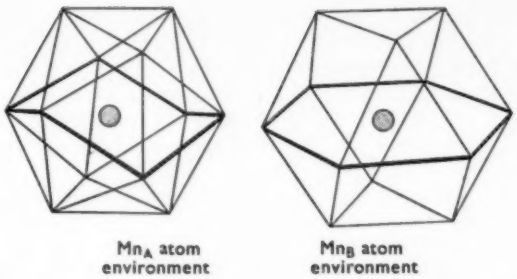

Fig. 7.—Environment of $12Mn_A$ type and $8Mn_B$ type atoms in β-manganese, to illustrate distortion of hexagonal plane.

Conclusions

(1) A compound isomorphous with β-manganese exists in the Fe-Cr-W-C system ; it is stable only at the highest solid temperatures, but is quenchable.

(2) The phase (denoted here by π) is a high-temperature form of χ-phase, the α-manganese isomorph. However, the composition and solubility regions of χ and π do not necessarily coincide.

(3) Carbon is an integral element in forming the π structure. In the carbon-free systems Fe-Cr-Mo and Fe-Cr-W, the occurrence of π could not be confirmed, but it is not excluded, as the phase may be unquenchable.

(4) The χ-phase in Fe-Cr-Mo and Fe-Cr-W possesses a large solubility for carbon ; the phase is able to play the double role of (*a*) an intermetallic compound, and (*b*) a "carbide."

(5) A reaction $\pi \longrightarrow \chi + \alpha$ is observed (where α = greatly expanded ferrite) ; this reaction can take several variants, and can occur with decreasing quenching temperature, decreasing rate of cooling, or as a result of cold-work.

(6) The π-phase forms on solidification (probably by a peritectic reaction), but its formation may be inhibited to varying degree depending on the manner of thermal traverse of the region between liquidus and solidus.

(7) The lattice-spacings of π-phase vary between 6·275 and 6·39 kX.

(8) The two types of manganese-atom known from Preston's β-manganese structure will, in π, provide sites predisposed to filling by either (Cr, W) or (Cr, Fe) atoms preferentially. The structure contains sufficient holes to permit some interstitial carbon. (No structure-determination of π-phase has here been attempted.)

(9) Wide variations occur in the lattice-spacings of χ and α ; these reflect solubility variations, and (together with those in π) probable age-hardenability over successive high-temperature ranges ; potentially this might favour creep resistance.

(10) χ (Fe-Cr-Mo) and χ (Fe-Cr-W) (as distinct from carbon-bearing χ) are located in both systems between the σ- and ξ-phase fields. Carbon-free χ-phase forms assemblies with σ, *N*, α and

γ-phases, and such sequences can be systematically produced by varying composition, temperature, or time at temperature.

(11) As χ (Fe-Cr-W) dissolves increased interstitial carbon, an increased tungsten content can be accommodated in the lattice. In the Fe-Cr-Mo-C system, a carbon-bearing χ-phase also exists.

(12) χ-Phase and η-carbide form alternative compounds at a constant-carbon level in the Fe-Cr-W-C system, depending on chromium content, and a steady transition occurs from η-bearing high-speed steel type to χ-bearing constitutions; the occurrence of χ-phase and π-phase in some practical tool-steels after certain thermal histories is indeed a metallographic possibility to be considered.

(13) From the aspect of structure systematics, all four allotropic forms of manganese (α, β, γ and δ) might now be considered as established in non-manganese bearing transition metal systems, since the γ- and δ-manganese structures may be simply related to the associated austenites and ferrites.

Note added in proof: It has been learned that Dr. K. H. Jack (King's College, Newcastle upon Tyne), has recently found nitrogen-bearing phases of the β-manganese structure in the Fe-Mo-N and associated systems. These results, which form a most interesting extension to the above, shows that interstitial nitrogen can take the part of carbon.

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In the Birthday Honours List

(*Continued from page 2*).

M.B.E.—continued.

BRIGADIER G. G. R. WILLIAMS, Civil Defence Officer, Mather and Platt, Ltd.

R. G. WINTON, Director and Technical Manager, Lansing Bagnall, Ltd.

J. WRANN, Chairman and Managing Director, Agamemnon Boat Yard, Ltd.

B.E.M.

T. D. BUCKLE, Laboratory Worker, Grade A, Atomic Weapons Research Establishment.

J. CONNOR, Foreman Blacksmith, Clyde Alloy Steel Co., Ltd.

E. G. COTSWORTH, Leading Draughtsman, Royal Aircraft Establishment.

T. W. DAVIES, Sheet Metal Worker, Marston Excelsior, Ltd.

J. ECKERSLEY, Joiner, W. T. Glover and Co., Ltd.

J. L. HUNTER, Foreman Steel Erector, Harland and Wolff, Ltd.

G. KENNEDY, Research and Development Craftsman Special (Instrument Maker), Royal Aircraft Establishment.

J. H. LAING, Skilled Machinist, English Steel Corporation, Ltd.

A. D. MCFARLANE, Foreman Erector, George Clark and North Eastern Marine (Sunderland), Ltd.

H. MOORHOUSE, Foreman Electrician, Harland and Wolff, Ltd.

A. C. PINCOTT, Laboratory Superintendent, Turbine Systems Development, Plessey Co., Ltd.

V. S. SACKETT, Leading Draughtsman, Signals Research and Development Establishment, Ministry of Supply.

D. SPENCE, Site Welding Engineer, Whessoe, Ltd. (Chester).

F. W. WATSON, Superintendent, Automatic Machine Shop, Simmonds Aerocessories, Ltd.

A. WATT, Mechanic Examiner, Inspectorate of Electrical and Mechanical Equipment, Ministry of Supply.

J. W. WOOLTORTON, Foreman, F.N.F. Machinery Manufacturing Co., Ltd.

J. H. YARDLEY, Foreman, G. A. Harvey and Co. (London), Ltd.

Laing-Ferguson Formed

IT is jointly announced by John Laing & Son, Ltd., and The H.K. Ferguson Company of Great Britain, Ltd., that the two companies are forming a separate association in the name of Laing-Ferguson to provide a complete and comprehensive construction service to the chemical, processing, and manufacturing industries. The integration of all aspects of construction under a single controling responsibility has already proved a means of achieving a significant and much needed speed up of completion schedules in this class of work. The Laing organisation is well known both in Britain and in the Commonwealth for its achievements in building and heavy civil engineering work for industry. Notable industrial projects in recent years include the twin automatic piles in West Cumberland for Britain's first plutonium-producing establishment, heavy foundations for the cold reduction mill at Abbey Works, and extensive construction work for Britain's oil refining and petro-chemical industries. The Ferguson Company is a subsidiary of The H.K. Ferguson Company of America—an organisation of world-wide repute for its experience in providing complete process plants, manufacturing plants and laboratories for a wide range of industries—and is already established in this country. It has worked successfully for such companies as Thomas Hedley & Co., Ltd., and for Imperial Chemical Industries, Ltd., and has collaborated with John Laing & Son, Ltd., on the new foundry for the Ford Motor Company at Dagenham—part of a vast expansion scheme.

Relative Creep Resistance of Cast Al-Si-Cu Alloys to LM4 and LM21*

By J. McKeown,† D.Sc., M.I.Mech.E., F.I.M. and R. D. S. Lushey‡

(*Communication from the British Non-Ferrous Metals Research Association*)

Comparative creep tests on cast aluminium-silicon-copper alloys to LM4 and LM21, containing, respectively, 0·35% and 2% zinc, show that there is no marked difference in behaviour at 200° C. in the normal life of an internal combustion engine.

A PREVIOUS paper—"Some Effects of Variation in the Zinc Content on the Mechanical Properties and Corrosion Resistance of Aluminium-Silicon-Copper Alloys"[1]—showed that with both 0·05% and 0·15% magnesium there was no appreciable change in any of the properties, tensile strength, proof stress and ductility with increase in the zinc content from 0·5 to 3·0%. The changes in properties resulting from natural ageing during a total period of 12 months of exposure outdoors were also independent of the zinc contents of the materials. There are now two specifications for such alloys, LM4 permitting up to 0·5% zinc and LM21 permitting up to 2% zinc, the other composition requirements being the same. Castings to LM4 are frequently used in engine applications at temperatures up to about 200° C., and the following tests were carried out to compare the creep properties of LM4 and LM21 alloys. The creep tests have been made at 200° C. and at two stresses, 3 and 5 tons/in.², on samples of LM4 and of LM21 containing, respectively, 0·35% and approximately 2% zinc, each with 0·11–0·13% magnesium. The duration of the tests was 6,500 hours (9–10 months).

Some irregularities were observed in the creep curves, the rate of creep accelerating over 100 to 300 hours and then returning to a lower rate. The cause of these is not clear, but they were observed with both materials.

The tests show that there is no marked difference at a temperature of 200° C. in the creep resistance of the alloys to specifications LM4 and LM21.

Experimental

The materials were provided, by a member company, in the form of A.I.D. sand cast test bars approximately 1 in. in diameter. Creep specimens having a diameter of 0·357 in. on a parallel length of 5 in. were machined from these bars. One creep specimen of each material was sectioned longitudinally and transversely for determination of grain size. For the LM21 specimen, the grain diameter ranged from 0·25 to 0·45 mm., and for the LM4 specimen from 0·25 to 0·46 mm. The average of 12 determinations on each material gave 0·37 mm. for the LM21 and 0·30 mm. for the LM4.

Two creep specimens of each material were loaded into cold furnaces and raised to temperature over a period of 4 hours and held at temperature for a further 20 hours before being loaded. One specimen of each material was loaded at 3 tons/in.², the other at 5 tons/in.². Temperature control was ± 1° C., and temperature uniformity along the 5 in. gauge length ± 1° C. Creep strain was measured to $\pm 2 \times 10^{-5}$.

Results of Tests

The results of the tests are given in Table I and the creep curves are plotted in Fig. 1. All the curves show some irregularities in rate of creep, but the cause of these

[1] METALLURGIA, 1955, **51**, 115–119.

* The information contained in this paper was made available to members of the B.N.F.M.R.A. in a confidential Technical Memorandum issued in March, 1957.

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‡ Research Assistant, Mechanical Testing Section, B.N.F.M.R.A., London.

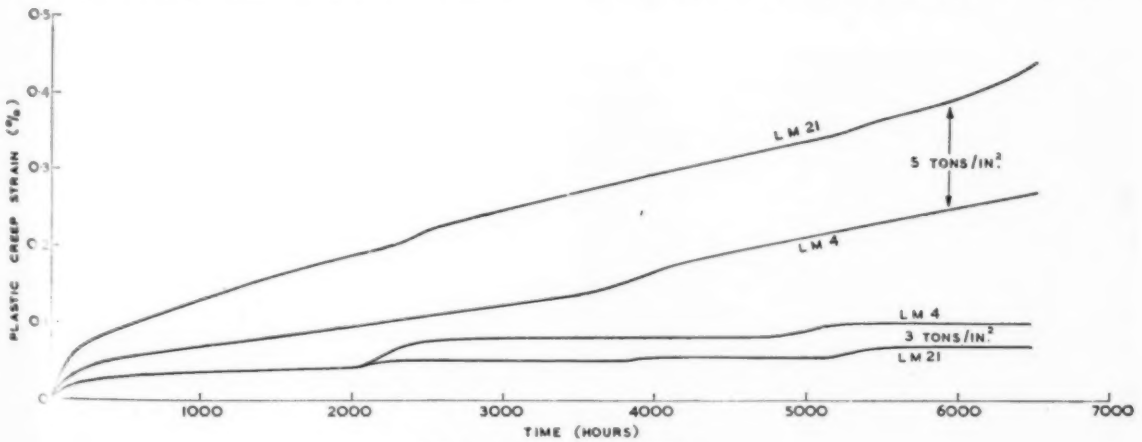


Fig. 1.—Creep tests at 200° C.

TABLE I.—CREEP TESTS ON LM4 AND LM21 ALLOYS AT 200° C. (A.I.D. SAND CAST TEST BARS).

Material	Stress tons/in.²	Plastic Creep Strain (% at — hours)					
		1,000	2,000	3,000	4,000	5,000	6,500
LM4	3	0·030	0·040	0·080	0·086	0·090	0·102
(0·30 mm. grain diameter)	5	0·070	0·100	0·132	0·170	0·210	0·270
LM21	3	0·036	0·044	0·050	0·056	0·056	0·068
(0·37 mm. grain diameter)	5	0·132	0·186	0·248	0·294	0·336	0·434

		Total Strain (% at — hours)					
		1,000	2,000	3,000	4,000	5,000	6,500
LM4	3	0·106	0·114	0·154	0·158	0·166	0·176
(0·30 mm. grain diameter)	5	0·190	0·222	0·254	0·292	0·336	0·392
LM21	3	0·106	0·112	0·122	0·126	0·128	0·140
(0·37 mm. grain diameter)	5	0·254	0·306	0·368	0·412	0·458	0·554

is not known. It was certainly not due to lack of temperature control, because the changes in creep rate extended in most cases over a period of at least a week, and specimen temperature was checked daily. At a stress of 3 tons/in.², the creep of the two alloys was the same for the first 2,000 hours, after which the first acceleration of creep rate occurred. This effect was more pronounced in the LM4 specimen and lasted longer, with the result that the creep curves separated, but subsequently remained reasonably parallel. At 5 tons/in.² the primary rate of creep was greater for the LM21 specimen, and the accelerated creep stage occurred earlier in this specimen than in the LM4 one.

From these curves it appears that there is no marked difference in the creep behaviour of the two alloys at 200° C. The duration of the tests was similar to the normal life of an internal combustion engine, and if a total (elastic plus plastic) strain of 0·1% were permissible in service, a permissible service stress would be of the order of 2 tons/in.².

Acknowledgments

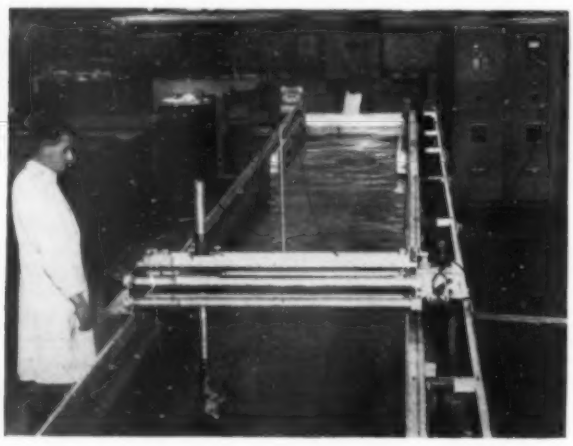
The authors are indebted to the Director and Council of the British Non-Ferrous Metals Research Association for permission to publish this paper.

Semi-Automatic Ultrasonic Flaw Detector

A SEMI-AUTOMATIC ultrasonic flaw detector developed for their own use by James Booth & Co., Ltd., is designed to scan automatically high strength alloy plates and various types of extrusion, and a continuous and permanent record of any flaw or defect in the materials is provided. The detector provides an extremely accurate cross-check on existing equipment, and has been put into routine use at their Kitts Green, Birmingham, works, where it is believed to provide facilities unequalled in this country for thorough and reproducible inspection.

The plates or extrusions are placed horizontally in a water-filled tank, 40 ft. long × 4 ft. wide, and a testing probe is moved over the upper surface. Longitudinal motion is provided by a motorised probe carriage running along the track of the tank, with the transverse motion provided by an adjustable screw which moves the probe itself into the desired position.

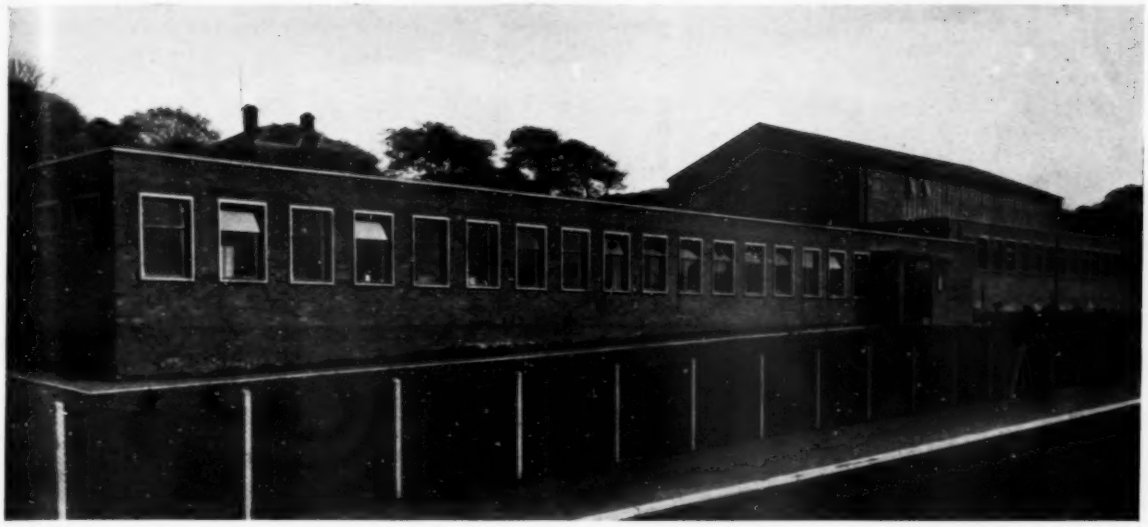
The probe is connected through a screened cable to an instrument console containing a standard ultrasonic flaw detector. The latter gives visual indication, in the form of peaks, of the transmission pulse, and also of the reflections from the upper and lower surfaces of the material being tested. A smaller peak between the two reflection peaks indicates a flaw or defect. Coupled to the detector are two standard monitors, one of which gives audible warning if the intensity of the transmission pulse falls below a predetermined level and the other reacts to defect signals above a certain magnitude.



The controller-recorder unit, also housed in the console, is visible mainly as a disc which rotates in sympathy with the motion of the probe carriage—one complete revolution corresponding to the length of the tank—and operates limit switches which will automatically reverse the direction of the carriage. The position of the switches are adjustable so that the probe can range over the complete length, or any required part only, of the tank. After the carriage has completed one "run" the probe would normally be moved transversely, say ¼ in., before the carriage is allowed to return.

The disc carries a sheet of Teledeltos electrosensitive paper which is charred locally by a small electric spark, passed from the end of the stylus coupled to the probe. The stylus moves radially over the paper in direct relation to the transverse movement of the probe—the combination of disc and stylus thus reproducing all movements of the probe in the horizontal plane. The electric spark is provided automatically by the defect monitor whenever it receives a defect signal above the preset magnitude. The resulting pattern of charred dots burnt into the Teledeltos paper corresponds to the pattern of flaws in the material being examined. To assess the actual magnitude of any particular defect, provision is made for the probe to be manipulated manually into the exact position over a flaw. The height of the peak shown on the standard ultrasonic flaw detector can then be measured and compared with the peak given by one or more special flat ended holes drilled in a series of test blocks.

A further feature, intended mainly for use by laboratory personnel in checking and development work, is the inclusion of a high speed recorder which will give a profile of the defect signal as the probe moves over a flaw. It will be of great value in resolving large diffuse defects of low reflecting power.



B.S.C.R.A.'s New Research Station

Formal Opening by Sir Harry Jephcott

THE new Research Station of the British Steel Castings Research Association at East Bank Road, Sheffield, was formally opened on Tuesday, June 4th, 1957, by Sir Harry Jephcott, Chairman of the Council for Scientific and Industrial Research. The Association—which is the successor to the Research and Development Division of the British Steel Founders Association, founded in 1950—was incorporated in March, 1953, and commenced to receive financial support from the Department of Scientific and Industrial Research in April, 1954. There are 58 members and 4 associate members, representing 80% of the U.K. steel foundry industry. Membership has increased by 33% in the last two years, and industrial income by 100% since 1953.

Prior to the move to East Bank Road, the Association headquarters were at Broomgrove Lodge, Sheffield, where laboratory facilities were almost non-existent. During the initial period of its existence, the Association placed research contracts with various universities, and Sir Harry Jephcott, at the luncheon preceding the Opening Ceremony, said that he imagined that now the Association had its own Laboratories it would wish to cut down some of this university work. He hoped that the connection would not be broken off completely, and commended the idea of supporting research studentships, which would maintain the interest of the university department concerned, and ensure that the Association was known to and appreciated by students in the science schools of the university.

The laboratories, experimental foundry and offices have been built and equipped in twelve months at a cost of £93,000, the whole of which has been accumulated out of revenue. The staff totals 48, of whom 10 are senior graduate investigators; 4 bursaries are maintained at universities.

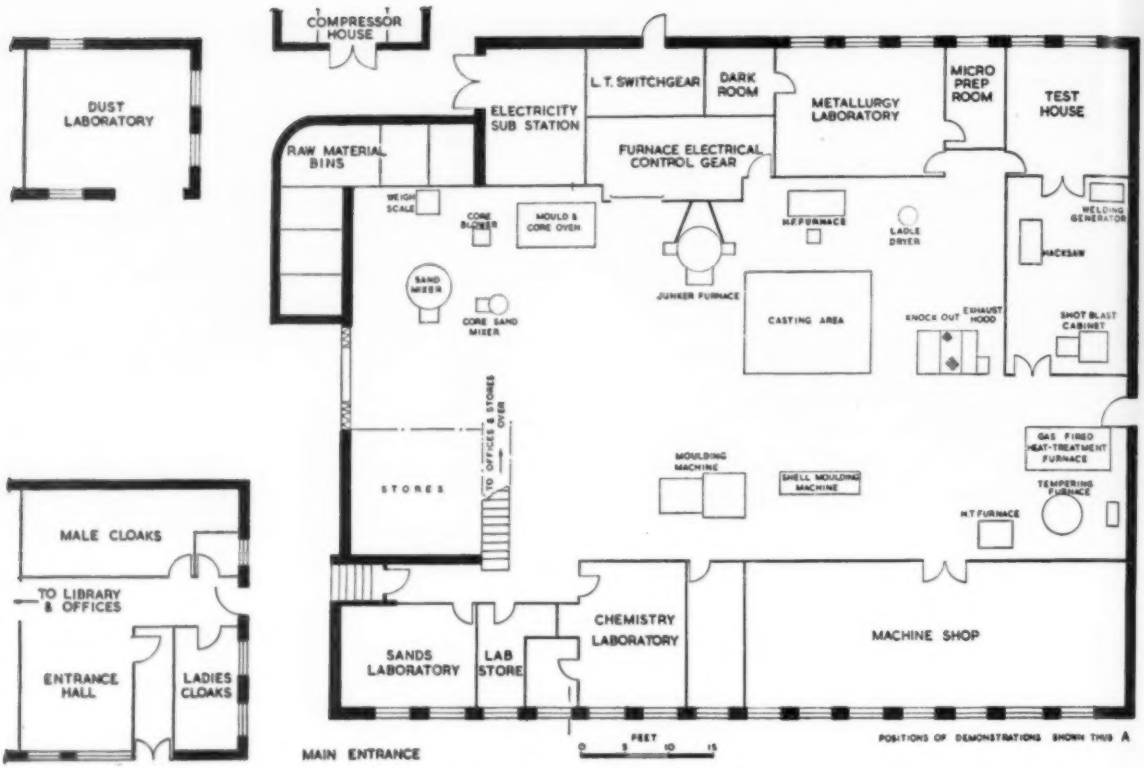
The results of research are published to members in the *Journal of the B.S.C.R.A.* and in *Research Reports. B.S.C.R.A. Abstracts* surveys the world's technical literature which is of interest to steel founders. Use is also made of films produced by the staff where they can help to record the progress of research or assist in its application in production.

Liaison with members is accorded the highest possible priority, up to 90% of those in the U.K. being visited by the staff each year. The annual conference is attended by a similar proportion of the U.K. membership, and about half the total membership is represented on five technical advisory committees, attendance at meetings of which averages 85%.

Experimental Foundry

The experimental foundry occupies the largest section of the new laboratories, with an area of 90 ft. × 40 ft., most of which is served by a Booth floor-operated 3-ton E.O.T. crane. The foundry roof is insulated and contains four opening ventilators. Good natural lighting is provided by continuous side and end wall glazing with opening lights. Artificial lighting is designed to provide a minimum of 12-ft. candles on the floor space; heating is by wall-mounted individually-controlled gas-fired radiant heating panels.

Provision has been made for all essential foundry operations. Sand mixing equipment includes an August-Simpson 5-cwt. capacity batch mix muller and a Fordath 80-lb. capacity core sand and shell moulding sand mixer. Moulding and core-making are provided for by a British Moulding Machine jolt squeeze unit and



Plan of the experimental foundry and laboratories.

a Titanette core blower, respectively, as well as facilities for hand moulding and core-making. A J.L.S. Engineering gas-fired air-circulating tray-type stove, with temperature controller and recorder is available for mould and core drying. A shell moulding machine has also been installed.

Among the investigations carried out in this field, reference may be made to the trials which have been conducted on simple pilot-scale wet and dry sand reclamation systems, both of which have been shown to be capable of cleaning used sand to such a degree as to be satisfactory for moulding purposes. It has also been shown that small soda ash additions to certain used foundry sands slightly improve the green strength properties and brings about some improvement in casting quality. A study has been made of the effect of heat on the properties of compacted moulding sands, including the determination of the strengths of the sands at high temperatures, their retained strengths on cooling back, and the effect of various factors on the decomposition rate of the clay.

Research followed by production trials has shown that imported Wyoming bentonite used for bonding moulding sand can be partially replaced by British kaolinite clays, with no loss in casting quality, and with a saving of £15,000 per annum to the steel founding industry.

The possibility of replacing resin bonded sands with thermally harcened sodium silicate bonded sands in shell moulding is being investigated, since such mixtures can be expected to prevent the surface defects now encountered in plain carbon steels when cast in resin bonded shells. The strength is adequate but the rate of build-up of the shell is low.

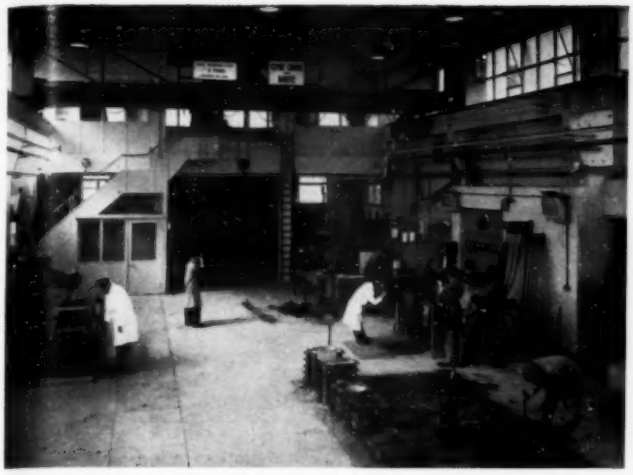
Data on the CO_2 hardening of sands bonded with commercial sodium silicates of different $Na_2O : SiO_2$ ratios have been obtained in the course of a study of the CO_2 sodium silicate process, and the effect of organic additions on the room and high temperature properties of silicate bonded sands has been determined.

Studies of the effect of varying squeeze pressure, jolt frequency and magnitude, and other variables in the compaction of moulding sand are in progress with a view to improving the uniformity of the density of moulds produced on jolt-squeeze moulding machines.

Two furnaces, one of 5 cwt. capacity and one of 30 lb. capacity are installed for the production of molten steel. The former is a basic lined Junkers-Birlec graphite rod resistor furnace suitable for pilot-plant scale steel-making research. These furnaces, which are made in sizes up to about 30 cwt., have a graphite resistor rod above the surface of the metal, and can be used like basic arc furnaces ; they are, however, much quieter in operation. The B.S.C.R.A. unit has a power consumption of 2,000 kWh./ton for the first heat and 1,400 kWh./ton for subsequent heats. The smaller unit is a Birlec spark-gap oscillator high frequency furnace for the melting of selected charge material.

From the data obtained from a survey of oxygen injection practice in the foundries of members, information has been obtained which shows relationships between oxygen required and carbon to be removed, and the effect of prevailing oxidising conditions and the volume of oxygen used on the efficiency of carbon removal.

A Honeywell-Brown high speed multipoint recorder is available for use in studies of the solidification of steel



The experimental foundry, showing the moulding and core-making facilities, sand preparation plant and the 5-cwt. capacity graphite rod resistor furnace.

The Birlec 30 lb. capacity high frequency electric melting furnace.

castings. The temperatures of twelve thermocouples can be recorded at intervals of 2½ seconds, so that each couple is recorded every half minute. Comparative studies have been made between castings made in stearin wax and in steel to determine how far the wax will simulate the form and distribution of shrinkage cavities found in steel.

A Spenstead ventilated stationary knock-out grid is provided near to the casting area, and an adjacent fettling area is screened off from the remaining foundry floor. It is equipped with a Wicksteed power saw, a small Tilghman shot blast cabinet, a powder washing torch and dispenser, an air carbon arc torch, a 600 amp. welding generator, gas welding equipment and the usual range of pneumatic tools. The air carbon arc torch is used for the removal of excess metal and for the gouging out of defects. There is no risk of starting or propagating cracks in low carbon steel, but precautions are necessary with steels tending to air harden. This type of torch is not so effective where there is burnt-on sand, but this can be satisfactorily dealt with by the powder washing process. Both these techniques have been introduced into U.K. steel foundries by the Association ; they show economic advantages and some improvement in working conditions, when compared with orthodox methods of fettling.

Heat treatment facilities comprise a Brayshaw gas-fired recirculating furnace capable of a maximum operating temperature of 1,250° C., an Amalgams electric muffle furnace for use up to 1,000° C., and a Birlec 20 kW. vertical forced air circulation tempering furnace. Oil and water quenching tanks are also provided. Temperature controlling and recording equipment includes controller-recorders by Honeywell-Brown and Foster and an Ether Transitrol programme controller.

Compressed air, three- and single-phase A.C. electricity, gas and water supplies are available at approximately 15 ft. centres on each side wall of the foundry, and a central under-floor duct provides conveniently for temporary service or drainage connections.

Situated in the same block as the experimental foundry are the sand laboratory, the chemistry laboratory, the machine shop, the test house and the metallurgy laboratory.

Tapping the 5-cwt. graphite rod resistor furnace.

Sand Laboratory

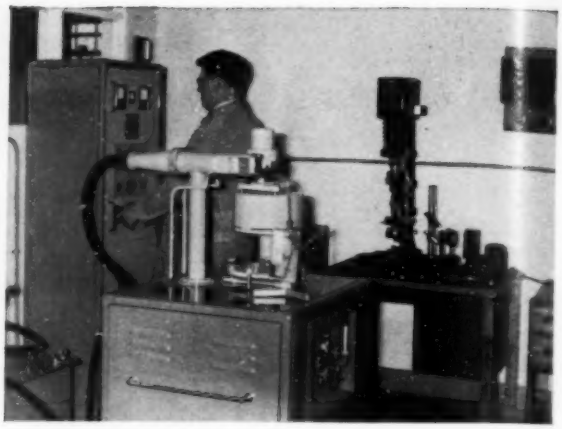
The sand laboratory is fully equipped for the routine examination and evaluation of new moulding materials, including sands, mould paints, moulding sand bonds and core binders, that might find application in steel foundries. It also serves as a control laboratory for the experimental foundry, and for the development of such special tests as may be required for research projects.

Special equipment includes a *p*H meter and a petrological microscope for the mineralogical examination of sands and bonding clays. Equipment for differential thermal analysis of clays and the determination of refractories of sands and bonding clays is to be installed.

Chemistry Laboratory

In addition to being used for routine analysis of steel and slags by normal chemical and absorptiometric

The Vickers projection microscope.



The Raymax 60 X-ray diffraction apparatus and the Watson microscope.

(Spekker) methods, the chemistry laboratory is also equipped for the assessment of silica in samples of foundry atmosphere dusts by semi-microanalytical methods, the determination of small quantities of alkali metals by means of an Eel flame photometer, and the estimation of hydrogen by the Henricot method.

The determination of the absolute hydrogen content of steel can only be achieved by vacuum fusion methods, but it is claimed that the Hennicot method, in which hydrogen is evolved from a chill cast sample at 300° C. over mercury, yields 83–87% of the absolute hydrogen value, and may therefore be useful for control purposes.

Fluorspar has a pronounced effect on the chemical activity of steelmaking slags, and the determination of fluorine is therefore important. In the method used, the fluorine is evolved by steam distillation in a modified Kjeldahl apparatus, collected in standard caustic solution, and titrated with thorium nitrate, using Solochrome blue indicator.

Test House and Machine Shop

The test house is equipped to perform any of the mechanical tests required in British Standards for steel castings. A Denison Type T42/B4 self-indicating universal testing machine of 50 tons capacity is fitted with a load pacer, to enable any required straining rate to be used when making a tensile test. Accessories to this machine include bend testing and compression testing equipment. For the determination of tensile properties in thin sections, such as webs, or for examining variation in tensile properties in a larger casting section, a Hounsfield Tensometer is available, which uses miniature test pieces.

An Avery combined Izod/Charpy impact testing machine provides for the impact testing of square and round Izod test bars, and also square Charpy test bars. In addition, tension/impact tests may be made on this machine. Equipment is available in the test house for cooling impact test pieces to sub-zero temperatures, and for the determination of low temperature impact properties of steel castings. A Vickers diamond hardness testing machine and a Jackman Brinell hardness testing machine are also installed.

A machine shop is available for the preparation of test pieces, and for the making of experimental equipment and apparatus. It also serves as a pattern shop for the foundry. Its main equipment comprises two lathes, a universal milling machine, a shaper, a surface grinder and a pillar drill.

The dust research laboratory: the separation of a dust sample from the paper thimble in which it is collected by the Hexhlet sampling instrument.

Metallurgy Laboratory

For detailed examination and photography of specimens at high magnifications, the metallurgy laboratory is equipped with a Vickers projection microscope and a Watson vertical microscope. There is a bench microscope for more rapid visual work and a low power binocular microscope for the examination of fractures, etc. A separate room is provided for the preparation of specimens for macro- and micro-examination.

The laboratory is also equipped with a Newton Victor Raymax 60 X-ray diffraction unit for the determination of the constituents of steel foundry dust and of the composition of phases present in metallic materials, as well as for the recognition of non-metallic inclusions in steel and the microradiography of thin steel specimens. A photographic darkroom adjoins the laboratory.

An electric muffle furnace, with temperature controlling and recording equipment, and apparatus for the accurate calibration of thermocouples are amongst other

(*Continued on page 37*).

Overheating Effects in High Strength Aluminium Alloys

By T. R. G. Williams, M.Sc., A.I.M.

Engineering Laboratory, Southampton University

Overheating effects in high strength aluminium alloys can arise at both the homogenization and solution heat treatment stages. In this article, the author is mainly concerned with those resulting from abnormally low solidus temperatures or inadequate temperature control during homogenization.

IN order to obtain the highest mechanical properties in the wrought Al-Cu-Mg-Si alloys of the age hardening duralumin type (specifications B.S. 1470–HE 15 and HS 15) it is necessary to solution heat treat within 5° C. of the solidus temperature to dissolve the maximum concentration of alloying elements in the aluminium-rich solid solution prior to quenching. This practice requires careful control of temperature if overheated structures are to be avoided. It is also essential to control composition within close limits, and melting and casting practices must prevent the formation of coarse segregates which may result in abnormally low solidus temperatures.

The characteristics of the microstructures developed by over heating during solution heat treatment have been described by several investigators,[1, 2] and the following is a summary of some of the main observations :—

(1) Some of the intermetallic constituents are partly or wholly liquated, and the resulting fused liquid tends to spheroidize under surface tension effects. Fig. 1 shows a rosette of liquated material surrounded by a zone denuded of the finely dispersed intermetallics.

(2) Intermetallic constituents distributed near the grain boundaries tend to flow into them to form intergranular films. Figs. 2 and 3 are photomicrographs in the unetched and etched conditions, respectively, of such films. In this instance, the etched sample shows an area denuded of intermetallics following the path of the grain boundary.

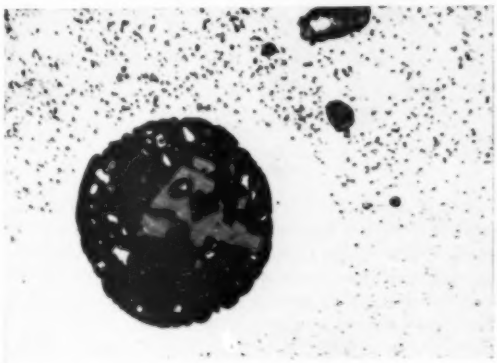


Fig. 1.—Overheated alloy showing rosette of liquated material surrounded by a zone denuded of the finely dispersed intermetallic constituents. × 1,500

(3) In severe types of overheating, continuous grain boundary films are formed, and the microstructure is similar to the grain boundary network normally associated with cast structures of aluminium alloys. Blistering of the surface nearly always occurs with this type of overheating.

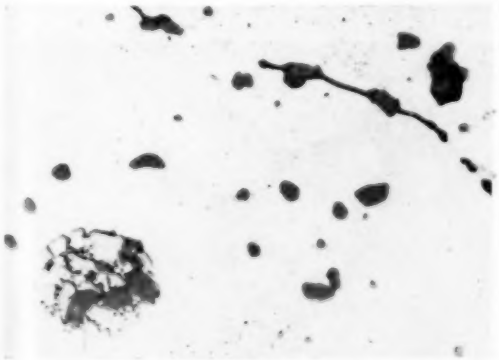


Fig. 2.—Intergranular films formed in overheated alloy by the intermetallic constituents in the vicinity flowing into the grain boundaries. Unetched. × 1,500

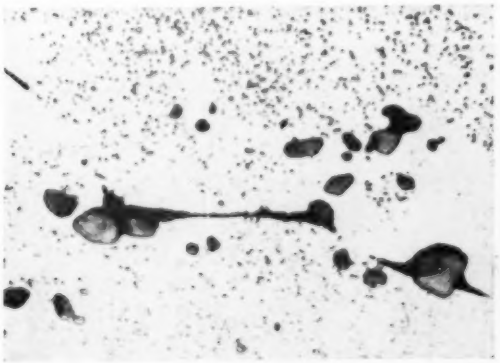


Fig. 3.—The same specimen as Fig. 2, but in the etched condition, showing an area denuded of intermetallic constituents following the grain boundary. × 1,500

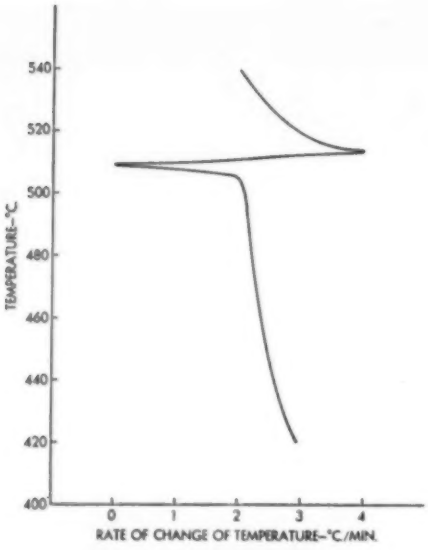


Fig. 4.—Heating curve.

Although the structures resulting from overheating during the solution heat treatment have been described in detail, there are no reports of the effect of overheating during preheat homogenization treatment on the structures subsequently obtained in solution heat treatment. Barker[3] has alluded to the possibility of confusing overheating effects arising in preheat with those arising at the later solution treatment stage: "However, the formation of rosettes alone, will not definitely establish the certainty of overheating, since various forms of preheating extrusion ingot will likewise cause rosettes."

Overheated structures can be produced during the preheat homogenization treatment in two ways:—

(1) Abnormally low solidus temperatures may be present in the cast structure due to coring effects. Liquation would then occur under the normal preheat temperature conditions.

(2) Inadequate control of preheat conditions may result in excessive temperatures.

Kasz and Varley[4] state that the danger of producing overheated structures due to the presence of abnormally low solidus temperatures is greater in semi-continuously cast ingots: "The very high chilling rate in semi-continuous casting has an additional consequence in the slabs being farther removed from constitutional equilibrium than are chill castings. Eutectics absent from the latter may therefore be present in the former, and by their presence demand more precise control of preheating conditions if overheating and cracking during rolling are to be avoided."

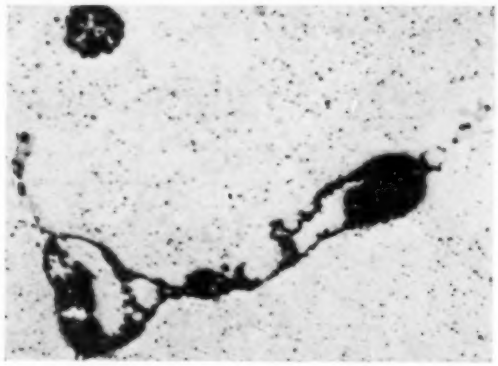


Fig. 7.—Structure resulting from liquation of some of the intermetallic constituents and eutectics during homogenization. × 750

The danger of developing excessively high preheat temperatures is aggravated when a wide range of alloys has to be preheated through the same furnace. The duralumin type alloys are generally preheated in the temperature range 400–460° C., whereas the aluminium-magnesium silicide alloys are preheated at temperatures up to 530° C., and commercially pure aluminium and the aluminium-1¼% manganese alloy as high as 550° C. Particular care must be taken in allowing adequate cooling times when changing over from these higher temperature alloys to the duralumin type material.

There is, therefore, a need for a metallographic technique which will differentiate between overheated structures developed in solution heat treatment and those developed at an earlier stage in fabrication.

Experimental Work

Plan

The experimental work was designed so that overheating occurred during the preheat homogenization

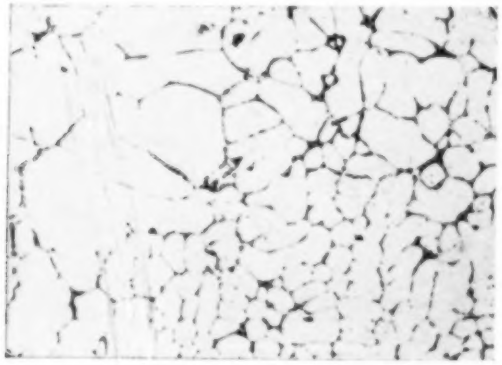


Fig. 5.—As-cast structure of the alloy used for the experiments. × 75

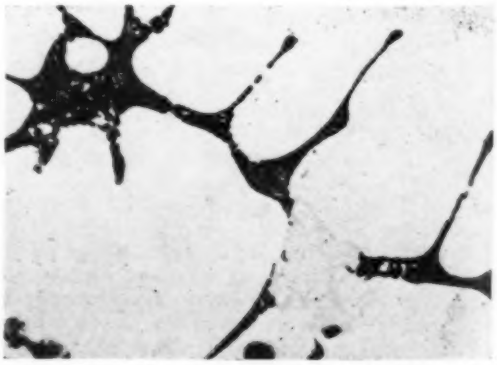


Fig. 6.—Grain boundary structure of the as-cast alloy used for the experiments. × 750

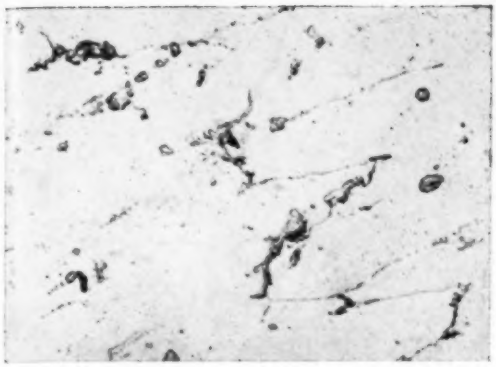


Fig. 8.—Structure after rolling and solution heat treatment. Unetched. × 250

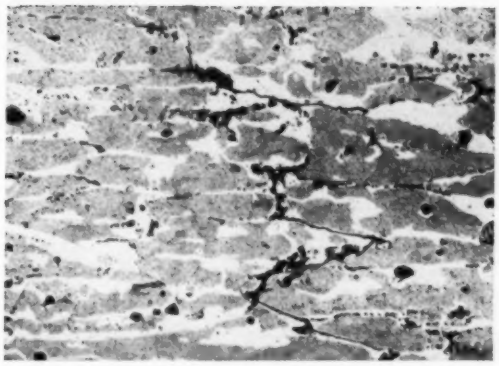


Fig. 9.—Structure after rolling and solution heat treatment. Etched 25% nitric acid. × 250

treatment of the cast structure of a high strength aluminium alloy, and the material was then rolled to sheet and solution heat treated. It was therefore necessary to carry out thermal analysis of the cast structure to determine the solidus temperature, in order to select homogenization temperatures at which liquation would occur. Care was taken not to exceed the solidus temperature of the alloy in subsequent thermal treatments, in order that the overheating effects observed in the solution heat treated sheet would be those resulting from overheating in preheat only, and so that these overheating effects would not be masked by liquation at later stages in fabrication.

Details

The sample of cast material was obtained from an ingot of high strength Al-Cu-Mg-Si-Mn alloy poured by the direct chill process. The sample—6 × 1 × ½ in.—was homogenized for 12 hours at 520° C., reheated at 460° C. before rolling down to 0·10 in. The 0·10 in. material was annealed 30 minutes at 460° C., cold rolled down to 0·060 in., solution-treated at 500° C. (1 hour soak) and quenched.

The high temperature homogenization treatment of 12 hours at 520° C. was carried out in an air furnace, and so was the reheating to 460° C. prior to hot rolling. A two-high experimental rolling mill was used for both hot and cold rolling. The annealing treatment of ½-hour soak at 460° C. (applied between the hot and cold rolling operations), and the final solution heat treatment of 1-hour soak at 500° C. were carried out in a salt bath.

Samples were obtained at various stages in fabrication for metallographic examination.

Results

Thermal Analysis

The heating curve obtained in the thermal analysis of the cast structure is shown in Fig. 4. The lowest arrest temperature is at 509° C.

Structure of the Cast Material

A large variation in cast grain size was observed—Fig. 5—and there is a complete grain boundary network of intermetallic constituents and eutectics. Details of the grain boundary are seen in Fig. 6. The Chinese script type of constituent was identified as α (Fe-Mn-Si-Al), and the remainder of the grain boundary area consists of eutectic structures.

Structure of the Cast Material after Preheating

Liquation of some of the intermetallic constituent and eutectics occurred during the preheat homogenization, as revealed by Fig. 7.

Structure of the Rolled and Solution Heat Treated Sheet

Figs. 8 and 9 reveal a part of the microstructure before and after etching in 25% nitric acid. Groups of intermetallics are connected by thin films which follow irregular paths through the structure. The films and

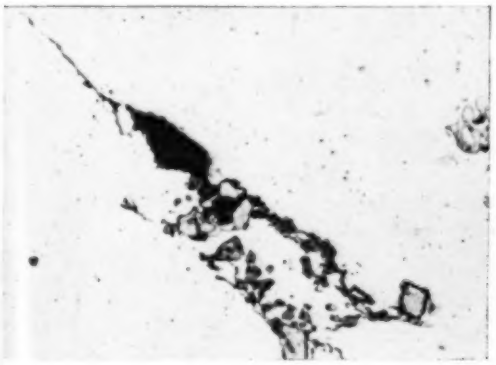


Fig. 10.—Films and intermetallic constituents in the rolled and solution treated alloy. × 1,200

Fig. 11.—Films and intermetallic constituents in the rolled and solution treated alloy. × 1,200

Fig. 12.—Structure of rolled and solution treated alloy near the edge of the sheet. Etched 25% nitric acid. × 75

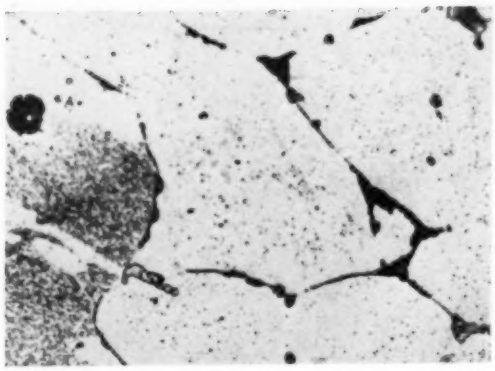


Fig. 13.—Junction between the dark and light etching zones. Etched 25% nitric acid. × 750

intermetallics are seen at higher magnification in Figs. 10 and 11.

Fig. 12 shows an etched area of the microstructure near the edge of the sheet. The structure can be divided into two zones—a white cellular zone in which the cells are outlined by films and cracks, and a dark etching zone similar to that shown in Fig. 9.

The junction between the two zones is seen at higher magnification in Fig. 13. The cellular structure of the white zone is again apparent, and in the dark etching area there is a concentrated dispersion of a finely divided intermetallic constituent. A rosette of liquated material is located at one position in the boundary between the zones. Figs. 14 and 15 are additional photomicrographs of the boundary between the two zones. In some parts of the structure this boundary is delineated by films, which are thickened in parts by globularisation, and the finely divided intermetallics of the dark etching areas are present in the structure right up to the boundary films.

Etching the sample with both 25% nitric and ½% hydrofluoric acid revealed a grain structure within both the white cellular and the dark etching zones—see Fig. 16.

Fig. 17 shows a back reflection X-ray photograph of the solution heat treated aluminium alloy sheet.

Discussion of Results

The preheat treatment at 520° C. caused liquation of some of the intermetallic constituents, which formed rosettes within the grains of the cast structure, and liquation films at the grain boundaries. Fragmentation of the larger constituents at the grain boundaries occurred during rolling, but the rosettes were not broken up and were similar in appearance to those formed by overheating in solution heat treatment, thus confirming Barker's[3] observations. An X-ray photograph of the solution heat treated sheet indicated that complete recrystallisation had occurred.

The dark and white areas revealed by etching in nitric acid (Fig. 12) are the grain structure of the original cast material. In the white cellular area, overheating has been severe and most of the intermetallic constituents have moved to the grain boundaries forming liquation films, some of which have globularised—see Fig. 14. On etching in hydrofluoric acid, the recrystallised grain structure is revealed, and Fig. 16 shows the grains formed within the cell outlines of the original cast structure. There are no liquation films present at these recrystallised grain boundaries. This is a radical difference between overheated structures formed in preheating and those formed in solution heat treatment.

Conclusions

Comparison of the microstructures developed in high strength aluminium alloy sheet material overheated during the preheat homogenisation treatment with those associated with overheating in solution heat treatment revealed the following information :—

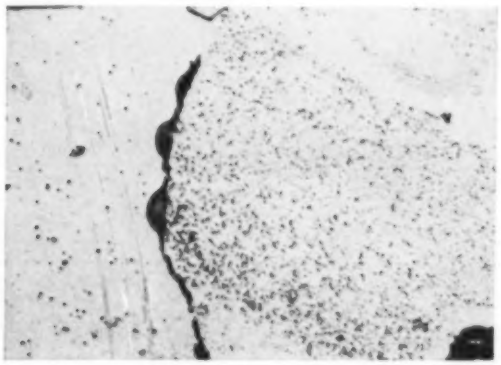


Fig. 14.—Junction between the dark and light etching zones. Etched 25% nitric acid. × 1,200

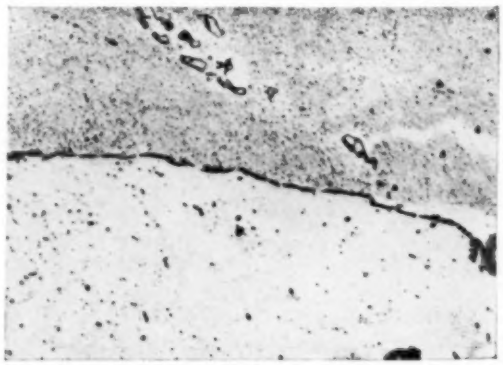


Fig. 15.—Junction between the dark and light etching zones. Etched 25% nitric acid. × 1,200

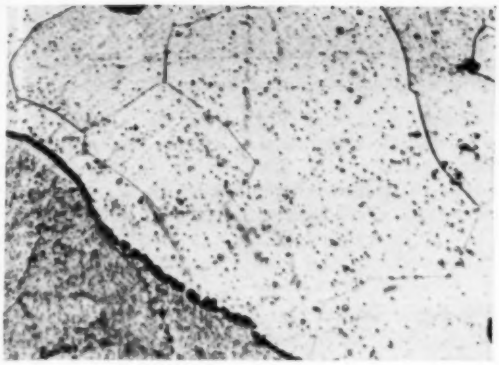


Fig. 16.—Junction between the dark and light etching zones. Etched 25% nitric and ½% hydrofluoric acid. ×1,500

(1) Rosettes of liquated material are present in both microstructures.

(2) Liquation films are formed at the grain boundaries of the cast structure in material overheated during preheating, whereas the liquation films are present at the boundaries of the recrystallised grain in material overheated in solution heat treatment.

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1 Crowther, J., "Overheating Phenomena in Aluminium-Copper-Magnesium-Silicon Alloys of the Duralumin Type," *J. Inst. Metals*, 1949–50, **LXXVI**, 201–236.

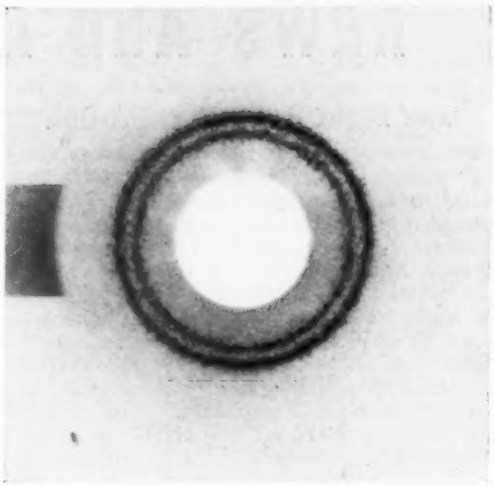


Fig. 17.—Back reflection X-ray photograph of the solution treated sheet.

2 Mason, N. H., Metcalfe, G. G. and Mott, B. W., "The Metallographic Examination of Aluminium Rich Alloys," *J. Inst. Metals*, May, 1944, 197–213.

3 Barker, L. J., "The High Temperature Oxidation of Aluminium Alloy Forgings," *The Iron Age*, May 9th, 1946, 61.

4 Knaz, F. and Varley, P. C., "The Hot Rolling of Aluminium and its Alloys" *J. Inst. Metals*, 1949–50, **LXXVI**, 410.

B.S.C.R.A.'s New Research Station

(*Continued from page 32*).

general equipment. A dilatometer and Jominy end-quench test rig are being constructed.

The effect on magnetic properties of variation in heat treatment, residual alloy and carbon contents have been studied, and it has been shown that economy in heat treatment furnace time is possible with improvement in the magnetic properties of some carbon steel castings.

Dust Laboratory

The dust laboratory is accommodated in a building separated from the experimental foundry block, and is devoted to the Association's work in the field of industrial health. For the collection of samples of airborne dust in foundries, various instruments are available, such as the thermal precipitator, the Owen's jet dust counter, the Konimeter and the Hexlet Sampler. The laboratory is equipped with these instruments and with apparatus for the assessment of dust samples collected by them. A dust tunnel is installed for calibrating and correlating the sampling instruments, for generating synthetic dust clouds simulating foundry atmospheres, and for other experiments relative to the sampling of airborne dust. Provision is also made for the temporary installation of equipment required for pilot-scale experimentation on problems associated with dust suppression. Apparatus of the type described by Stairmand for determining the efficiency of dust collectors is under construction.

There has for some time been a dust research station in Sheffield and systems developed for the control of dust generated by the use of pedestal and swing frame grinding machines are in commercial production, and are being widely used in British steel foundries.

In addition to dust suppression, the Association is interested in noise abatement, and is at present studying the measurement of noise level in steel foundries, as a preliminary to an investigation of certain aspects of noise suppression.

Future Expansion

The present buildings have a total floor area of approximately 12,000 sq. ft., and occupy about half the available site area. Provision has been made for adding a further floor to the single storey administration block —which at present houses the director and administrative staff, the library and information section, and the cine photography section—to provide additional accommodation for the research staff and laboratories.

Permanent Way Materials Production

(*Continued from page 8*).

plates are processed in the cold condition, eliminating the reheating stage. In such cases the bearing plate bar is sheared and punched at one stroke in a 500-ton electrically operated machine. Cold straightening, if required, follows immediately afterwards in a 150-ton hydraulic press. After inspection and before despatch, bundles of finished fishplates and bearing plates are dipped in suitable preservatives to prevent corrosion. The output of this plant is approximately 10,000 tons annually.

NEWS AND ANNOUNCEMENTS

The Fight Against Corrosion

INDUSTRY'S annual bill for corrosion losses—to take metallic corrosion in the U.K. alone—amounts to more than £600 million (this figure was quoted by Dr. W. H. J. Vernon at a recent meeting of the Institution of Civil Engineers). Now a special effort is to be made to cut down these losses. October 14th to 19th of this year will be "National Anti-Corrosion Week." During this period a new impetus will be given to the use of anti-corrosion products and services. New information on corrosion and its prevention will be disseminated, and the organisers hope that publicity given to the subject will lead to a new public estimate of its importance.

Two principal events will mark National Anti-Corrosion Week. There will be a two-day Corrosion Convention, to be held at Central Hall, Westminster, on October 15th and 16th. Papers will be given by leading authorities on many aspects of corrosion and its treatment, and delegates will attend from overseas as well as from this country. Engineering and technical societies, and Government departments, have been invited to co-operate.

Nearby, at the Royal Horticultural Society's Old Hall, there will be a three-day corrosion Exhibition—the first full-scale exhibition of anti-corrosion products ever to be held in this country. The Exhibition will be open from October 15th to 17th, and much space has already been booked by exhibitors. In addition to delegates to the Convention, and other engineers and technicians, the Exhibition will be open to the general public.

The Corrosion Convention and Exhibition are being organised by the publishers of *Corrosion Technology* (a journal of the Leonard Hill Technical Group). Application forms for registration for the Convention may be obtained from the Organiser, Corrosion Convention, Stratford House, 9, Eden Street, London, N.W.1.

Symposium on Micro-Chemistry, 1958

IT is proposed to hold an exhibition embracing "live" and "static" demonstrations of a new and novel nature, and in addition, displays of historical interest during the Symposium on Micro-Chemistry to be held in August, 1958. It is intended that the demonstrations shall cover all aspects of chemical analysis, and set periods will be allocated for the demonstrations in the Symposium scientific programme. It is stressed that it is the desire of the organisers to include all branches of pure and applied chemistry. Any who feel that they have potential exhibits of relevant interest are invited to send details to the demonstrations secretary, Mr. G. Ingram, Research Laboratory, Courtaulds Ltd., Maidenhead, Berks.

Materials Testing Mission to Visit U.S.A.

A MISSION comprised of experts from West European countries is to visit the United States for the purpose of collecting the fullest and most detailed information on the latest techniques and equipment used in American industry for testing and inspecting materials in course of manufacture in the engineering and electrical industries (including tests carried out in the metallurgical industries during the last stages of processing the products of those industries before they reach the engineering and electrical industries). Particular attention will be paid to non-destructive testing methods, but testing to destruction will also be studied. Although the main concentration will be on ferrous and non-ferrous metals, it is hoped that there will be opportunities for studying the testing of plastic materials or chemical products.

The programme in the United States is scheduled to last five weeks, starting at the beginning of October, 1957, so as to enable members of the Mission who wish to do so to take part in the Second World Metallurgical Congress to be held in Chicago from November 2nd to 8th, 1957.

Powder Metallurgy Joint Group

THE Councils of the Iron and Steel Institute and of the Institute of Metals have formed a Powder Metallurgy Joint Group, the objects of which will be to study the science, technology and practice of powder metallurgy. Membership of the Joint Group will be restricted to members of the Iron and Steel Institute and of the Institute of Metals, though the meetings of the Group, as of the two Institutes, will be open to non-members.

The Inaugural Meeting of the Group will be held at Church House, Great Smith Street, London, S.W.1, on Wednesday, December 4th, 1957, from 10-30 a.m. to 4-45 p.m. In view of the number of other meetings already arranged, including two in Europe on powder metallurgy, an earlier meeting is considered inadvisable. Further meetings of the Joint Group are being planned for 1958.

The activities of the Joint Group will be administered by a Powder Metallurgy Joint Committee. Lt.-Col. S. C. GUILLAN has agreed to act as Secretary, and further particulars may be obtained from him at 17, Belgrave Square, London, S.W.1.

Import Duty on Nickel and Ferro-Nickel

THE Treasury have made an Order which continues for a further period of one year from May 13th, 1957, the current exemption from duty under the Import Duties Act, 1932, of certain forms of nickel and ferro-nickel alloys. The new Order also extends the exemption of duty, for the same period, to nickel in the form of briquettes. Copies of this new Order, the Import Duties (Exemptions) (No. 5) Order 1957 (S.I. No. 785) may be obtained from Her Majesty's Stationery Office or from any bookseller (price 3d., by post 5d.)

Official Approval for Kanigen Plate

THE Kanigen plating process—now being operated on production scale in this country by Albright & Wilson (Mfg.), Ltd., who are also the sole licensees for the new process in the U.K., Eire and Denmark—has recently been given the Ministry of Supply Reference No.

DTD 900/4505. The Ministry have at the same time indicated their approval of the application of Kanigen to certain carbon and low alloy steels, stainless steels and aluminium. Similar approval has been given by the Air Registration Board—Reference No. AI/5112/57.

S.C.I. Corrosion Group

As part of the programme for 1957–58, the Corrosion Group of the Society of Chemical Industry is planning a Symposium on Corrosion in Road Motor Vehicles, to be held in March, 1958. Joint meetings with the Manchester and Newcastle Local Sections, and with the London Section of the Institute of Metal Finishing will be included in the programme. Subjects for discussion will include titanium, stress-corrosion cracking, corrosion in power-plant boilers, protection of magnesium alloys, testing metal coatings, protection of agricultural spraying equipment, and facilities available and required for teaching corrosion science. The Spring Lecture will be delivered by Dr. W. H. J. Vernon.

Iron and Steel Import Duties

Under the Import Duties (Exemptions) (15) Order, 1956. the import duties on blast-furnace ferro-manganese and on a wide range of iron and steel products are suspended until September 18th, 1957. After consultation with the Iron and Steel Board about the supply position, Her Majesty's Government have decided to make a new Order which, with some exceptions, prolongs the suspension of import duty on these goods until March 18th, 1958. The exceptions are light bars and rods (other than in coils), light sections and hoop and strip not exceeding 18 in. in width. Duty on these products will be restored on September 19th, 1957. The new Order does not affect iron and steel plates, on which duty is already suspended until March 18th, 1958. This new Order, the Import Duties (Exemptions) (No. 6) Order, 1957, (S.I. No. 925) will come into operation on September 19th, 1957. Copies of the Order may be obtained from Her Majesty's Stationery Office or from any bookseller, price 2d. (by post 4d.).

Meehanite Conference

The Conference of European Members of the International Meehanite Research Institute, held at the Grand Hotel, Brighton, May 28th–30th, was attended by over 100 representatives of foundry and engineering firms from almost every country in Western Europe. The purpose of the Conference was to hear and discuss recent developments in Meehanite foundry practice and in Meehanite metal—a high duty cast iron used in engineering construction all over the world. During the Conference, separate sessions were devoted to sales and engineering, new development, foundry operations, and efficiency.

Great interest was aroused by the announcement of a new machine known as the Meehanite-injector, which would revolutionise the treatment of cast-iron. It permitted a fully automatic processing for improving the properties of the metal to a very high standard, at a cost below that for ordinary iron by conventional methods. Another development discussed was the testing of castings by ultrasonics.

Methods for increasing efficiency in foundry operations were also discussed at length. It was shown how a British Meehanite foundry had raised its productivity and reduced its costs by the use of scientific work study principles. The increased output and lowered costs had been obtained with less manual effort and greater earnings by the men doing the work. The study of plant layout for increased productivity received considerable attention. A foundry model occupying 90 sq. ft. complete in every working detail, was sent over from Holland, and the proposed layout was the subject of a great deal of useful comment and discussion.

Electric Steel Makers' Guild

A new technical society to be known as the Electric Steel Makers' Guild has recently been formed, the purpose of which is to promote progress in the manufacture of steel for commercial purposes in electric melting furnaces, and to encourage free discussion and exchange of information of mutual interest to members.

Membership is limited to executives who are regularly employed directly in the manufacture of electric furnace steel for commercial use, and meetings which will be held two or three times each year will be quite informal. No records of technical discussions will be made or published and members will be encouraged to discuss freely their own and others' problems. A similar Society which has been in existence for the past 25 years in the U.S.A. has been highly successful and enjoys great popularity in the steel industry.

The officers appointed for the first year are : *President* —Mr. R. Lamb (Hadfields, Ltd.), *Vice-President*—Mr. F. T. Bagnall (S. Fox & Co., Ltd.), and *Secretary*—Mr. A. Mettam (English Steel Corporation, Ltd., Grimesthorpe Works, Sheffield, 9.

Flames and Industry Symposium

Organised by the Institute of Fuel, by arrangement with the British Flame Research Committee of the International Flame Radiation Research Foundation, a one-day Symposium on Flames and Industry will be held at the Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, on Wednesday, October 9th, 1957.

The papers to be presented will deal not only with results of research on flame radiation, but also with the significance in practice of these results in various industrial applications including steel, glass, oil, cement, steam boilers, gas turbines and general furnace practice.

Further particulars and forms of enrolment may be obtained from the Secretary, The Institute of Fuel, 18, Devonshire Street, Portland Place, London, W.1.

Coking Plant Order

Woodall-Duckham Construction Co., Ltd., of London announces that it has just received the order to extend the coking plant at the Redbourn Works, Scunthorpe of Richard Thomas and Baldwins, Ltd. The order, which is valued at over £1¼ million, includes two further batteries, totalling 62 coke ovens, with a daily coal carbonising capacity of some 1,300 tons, by-product recovery plant, and coal and coke handling plants. The three batteries of W-D ovens now operating at Redbourn carbonise over 2,000 tons of coal daily.

Personal News

KELVIN & HUGHES (INDUSTRIAL), LTD., have appointed MR. J. R. TAYLOR as Area Engineer for the West of England. His new address is " Garth," Edward Road, Walton St. Mary, Clevedon, Somerset (Tel. : Clevedon 3535).

MR. J. H. MAYES, formerly Assistant General Sales Manager, is now General Sales Manager of Northern Aluminium Co., Ltd., in succession to MR. S. E. CLOTWORTHY who has been appointed Managing Director. MR. D. A. CORBETT-THOMPSON, Manchester Sales Area Manager, is to be Sales Manager responsible for Export Sales ; MR. E. D. ILIFF, Manager of the Sales Development Division at Banbury is to be Sales Manager responsible for Sales Development, Advertising and Publicity ; MR. F. LAYTON, Manager of the Sales Administration Department at Banbury, is to be Sales Manager responsible for all Sales Administration ; and MR. D. A. PINN, Manager of the Export Sales Department is to be Sales Manager responsible for all Domestic Sales. It is intended that these four Sales Managers will all operate from the Company's London Office.

AT the Twelfth Annual General Meeting of the Federation of Light Metal Smelters, Mr. B. ENDLAR was re-appointed Chairman for the current year, and MR. R. HAHN was re-appointed Vice-Chairman.

MR. S. J. L. SMITH has been appointed Publicity Manager of The United Steel Cos., Ltd., in succession to the late MR. D. WILSON. He will be responsible to MR. E. T. SARA, Commercial Research Manager.

COSTAIN-JOHN BROWN, LTD., announced to-day that MR. E. MENSFORTH, C.B.E., has been appointed to the Company's Board of Directors.

MR. J. F. B. JACKSON, who in 1954 resigned as Director of the British Steel Castings Research Association to join the Board of A.P.V.-Paramount, Ltd., alloy steel founders of Crawley, Sussex, has also joined the Board of P.I. Castings (Altrincham), Ltd.

MR. J. P. BENNETT and MR. J. CARTWRIGHT have been appointed Directors of Taylor Bros. & Co., Ltd., Trafford Park Steel Works, Manchester (a subsidiary of English Steel Corporation, Ltd., Sheffield).

MR. W. A. J. SAYER, until recently Assistant General Manager of the Machinery Division of George Cohen Sons & Co., Ltd., has been appointed Managing Director of George Cohen Sons & Company (South Africa) (Proprietary), Ltd., 53, African Homes Trust Building, Commissioner Street, Johannesburg, and will shortly take up residence in South Africa.

MR. A. S. LODD has been appointed a Director of John Thompson Water Tube Boilers, Ltd., and London Manager of John Thompson, Ltd. At London office he succeeds MR. C. J. HOWARD, who was recently appointed Managing Director of John Thompson Water Tube Boilers, Ltd. At John Thompson, Ltd., Belfast, MR. J. BOYD has been appointed Area Manager, to represent all of the John Thompson Group companies in Northern Ireland and Eire. In the latter territory, in respect of John Thompson Wilson Boilers, Ltd., he will co-operate with agents, Messrs. William Peat and Company, of Dublin. He will open a new area office for John Thompson, at 26, Wellington Place, Belfast.

THE British Aluminium Co., Ltd., have appointed MR. S. M. LAWRENCE Export Sales Manager in succession to MR. P. J. FERGUSON who has resigned from the Company to take up an appointment outside the aluminium industry. MR. P. L. MARTYN, Assistant Manager (Home Sales), will take over responsibility for Unwrought and Special Products Sales Section in succession to Mr. Lawrence, as well as continuing to be responsible for sales promotion activities. MR. R. J. WALSH has been appointed Manager of the Manchester Branch Sales Office in succession to MR. J. R. WHITELEGG, who retires from the Company's service on July 17th.

BABCOCK & WILCOX, LTD., announce the appointment to their Board of Directors of MR. I. M. STEWART and the RT. HON. LORD BRIDGES, P.C., G.C.B., G.C.V.O., M.C., F.R.S.

MR. W. E. DICK has been appointed Editor of *Chemistry & Industry* the new weekly organ of the Society of Chemical Industry. Mr. Dick, who was for many years Editor of *Discovery*, succeeds MRS. BUSH, who retired at the end of June.

GROUP CAPT. J. A. KENT, D.F.C. and Bar, A.F.C., has been appointed Sales Manager, Kelvin & Hughes (Aviation), Ltd.

THE Lord President of the Council has appointed SIR HAROLD ROXBEE COX, and DR. C. J. SMITHELLS, M.C., to be members of the Council for Scientific and Industrial Research.

DR. A. G. E. ROBIETTE has resigned from the Board of John Miles & Partners (London), Ltd., but he will be retained by them in a technical advisory capacity. He is setting up as an independent metallurgical consultant, and will be retained by metallurgical companies in this country, South Africa, and the United States. For the time being his address is Bury Farm, Bovingdon, Hertfordshire.

THE honorary degree of Doctor of Laws was conferred upon MR. S. WINGATE, President of The International Nickel Company of Canada, Ltd., at the Annual Convocation of The University of Manitoba.

MR. J. H. GAMESON has recently joined Murex Welding Processes, Ltd., as assistant to the Publicity Manager. Mr. Gameson was previously the Publications Officer and Editor to the British Welding Research Association, 29, Park Crescent, London, W.1.

MR. V. NEALE, General Production Controller of Geo. Salter & Co., Ltd., has been awarded a travel scholarship by the Birmingham College of Technology in connection with his work in the Department of Industrial Administration.

Obituary

We regret to record the death of the following :—

SIR ALFRED HERBERT, K.B.E., Founder, Chairman and Managing Director of Alfred Herbert, Ltd., who died on May 26th, 1957, in his ninety-first year.

DR. N. E. RAMBUSH, Chairman and Managing Director of The Power-Gas Corporation, Ltd., who died on May 15th, 1957, at the age of sixty-eight.

MR. A RUBIN, of Zürich, who represented Edgar Allen & Co., Ltd., for the sale of trackwork in Switzerland for over forty years, until his retirement in 1954.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Surface Active Agents

SURFACE active (wetting) agents are effective at very low concentrations (often only 0·01%) for improving the efficiency of many wet metal treatments, in which, by reducing the surface and interfacial tension of the liquid, they assist penetration and at the same time improve drainage, thus reducing drag-out and carry-over and increasing the overall speed of operation.

These advantages are widely recognised, yet the use of such agents has hitherto been limited because they are seldom sufficiently stable in the strongly acid or alkaline conditions common in metal treatment. Belloid M3 and Belloid M7 are non-ionic wetting agents specially developed by Geigy for use in these conditions. Their stability to acids, alkalies and oxidising agents is far higher than that of most anionic or cationic, and even of many non-ionic, surface active agents. They are readily soluble in water at all concentrations, though they are normally used at rates as low as 0·01–0·05%. Belloid M3, however, is somewhat less soluble in alkali at the high concentrations used in metal treatment, and is therefore more suitable for use in acid conditions. Belloid M7 can be safely used in strongly alkaline baths. In acid pickling, cleaning and de-rusting baths, Belloid M3 promotes attack on the corrosion products while the basis metal itself is spared. Belloid M7 is similarly effective in alkaline baths, and is a powerful emulsifier of grease. Both are useful in rinsing and phosphate coating, and also in electroplating, where they improve the current efficiency of the bath and accelerate drainage.

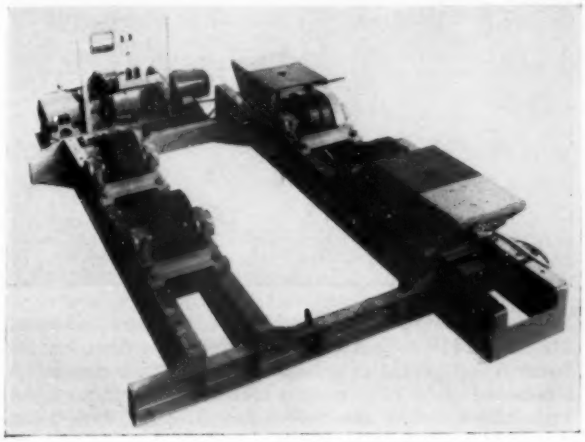
Belloid M3 and M7 are available in the form of soft waxes, but, for convenience in view of the small amounts needed, they can also be supplied as aqueous solutions.

The Geigy Company, Ltd., Rhodes, Middleton, Manchester.

Welding Roller Bed

THE medium series fixed roller bed fabricated by Quasi-Arc, Ltd., has now been re-designed to incorporate improvements and new distinctive features. The base frame is fabricated from mild steel rolled sections and plate. On the drive unit are mounted two carriages, each carrying two 16 in. diameter rolls. These are rubber tyred to give ample traction, while accommodating surface irregularities of the vessel.

The drive equipment is also mounted on the carriages, and on each this consists of a 1 h.p. variable speed D.C. motor, driving through a double worm reduction unit to the roll shaft. The two motors are fed by a 2 h.p. Ward Leonard motor generator exciter set. This drive equipment provides an infinitely variable welding speed range between 5 in. and 50 in. per minute, and is capable of rotating a load of 24 tons. Control of the rotation speed is by means of a regulator mounted on a control box attached to the roller bed. The direction of rotation can be changed with the aid of a reversing switch. The rolls on either side can be quickly and simply adjusted to take vessels between 1 ft. and 12 ft. 6 in. diameter, and the centre-line of vessels in this range would coincide with the base frame centre-line of the roller bed.



The idler unit is of similar construction to the drive unit, with two carriages each carrying two 16 in. diameter rubber tyred rolls. Where an idler unit is supplied with the drive unit, the two are usually fitted together with spacers to form a rigid assembly capable of carrying a load of 12 tons. Greater weights up to 24 tons can be accommodated by using additional idler units in series. Two idler units can be joined together with spacers, as with the drive and idler unit, to form a double idler unit.

In addition to the medium series bed, the Quasi-Arc range of roller beds includes light and heavy series. A combination of power-driven and/or idler units can be assembled with these series also, to take vessels of varying weights outside the specified range of a single unit, and also of varying lengths. This is of particular value where additional support is required to obviate excessive deflections. The rolls can be adjusted for vessels of different diameters.

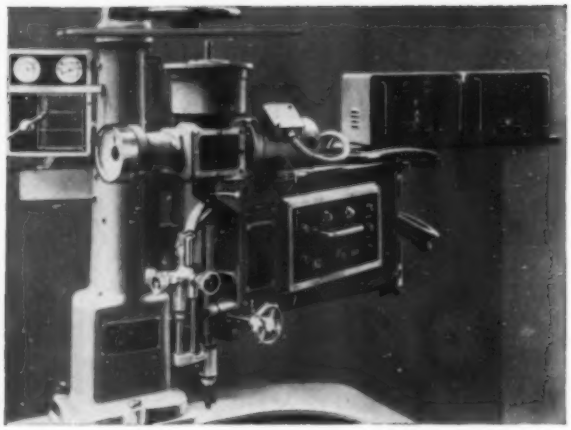
Where automatic welding heads are used, the vessels can be rotated on the bed for the circumferential seam welding at a widely variable range of welding speeds.

Quasi-Arc, Ltd., Bilston, Staffs.

Electronic Cutting Machine Control

AN electronic control unit to govern the cutting speed of their 36 in. universal cutting machine has been introduced by British Oxygen Gases, Ltd. The unit is known as Thyratron Control, and is placed on a wall shelf or table and connected to the machine by cables. It provides a higher standard of accuracy and quality of cutting by maintaining the drive motor at a constant speed at all settings, irrespective of any change in mechanical load. It also enables the machine to be pre-set to an accurate cutting speed, which is then achieved immediately from a standing start. Previously, when the initial speed adjustment was made while the cutter was in motion, an irregular start was sometimes made to the cut.

In addition, the control unit virtually eliminates speed variation due to normal mains voltage fluctuations.



With the new unit, the machine can be operated from 240, 220 or 110 volts A.C. No rectifier is required, and no warming-up period is necessary for the motor with its associated speed drift, so that once the cutting speed has been selected and the motor switched on, the speed remains constant until the cut has been completed.

*British Oxygen Gases, Ltd., Bridgewater House, Cleveland Row, St. James's, London, S.W.*1.

Photo-Transistor Relay

THE Magistor photo-transistor relay introduced by Metropolitan-Vickers is a new development in photo-electric controls. It is intended for use instead of mechanical limit switches in cases where it is not permissible or possible to touch the initiator, and where the speed of operation of a mechanical switch may lead to wear and failure. Typical applications are counting, level control, warning devices, height gauges, door control, smoke detection, inspection, edge position control, material handling, sequence checking and sorting.

This new relay dispenses with the need for thermionic valves, large photo-electric cells and h.t. supplies. The units are of small dimensions, and interconnections are reduced to two wires. The total power consumption is only 16 W.

The equipment consists of two small units—a lamp box and a receiver. The former contains a transformer supplying a prefocused lamp, whose light passes through a lens to produce a parallel beam. This light is directed on to the receiver unit, where it is focused by a lens on to the photo-transistor. The output of the photo-transistor energises a flux-resetting transductor, which controls a relay having changeover contacts. The relay operates when the light beam is broken.

The photo-transistor employed is a germanium-junction transistor, which is light sensitive and has the advantages of small size ($\frac{1}{4}$ in. diameter $\times \frac{1}{2}$ in. long), high sensitivity, low-voltage operation, robustness, and reliability. The flux-resetting transductor is simply a choke wound on a core of special material, whose impedance can be varied by the action of the applied voltage during the reverse half cycle; thus it responds to applied signals in approximately 1/100 second on a 50-c/s. supply. The circuit is so arranged that the transductor has very high impedance when light falls on the photo-transistor and a very low impedance when the light beam is interrupted. The transductor is connected in series with the relay coil across an external supply and acts like a magnetic switch, closing the circuit and energising the relay whenever the light beam is cut off.

The Magistor photo-transistor relay can also be supplied with electrical counters for speeds of up to 10 per second. Batching counters are available to deal with any predetermined quantity.

Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17.

Pressurised Fire Extinguisher

A NEW pressurised fire extinguisher of the vapourising liquid type has been developed by The Pyrene Co., Ltd. Its outstanding feature is a special squeeze-grip release valve that facilitiates one hand operation, enables the extinguisher to be used to the maximum advantage, and provides perfect on-off control of the discharge of fire fighting liquid.

Other features of the new extinguisher are a special locking device which provides added security against accidental discharge and vibration, and a small pressure gauge which allows the pressure within the container to be checked instantly at any time. This gauge also simplifies the process of recharging. The extinguisher may be recharged on the spot by filling with Pyrene liquid or CB and pressurising from a factory or garage air line.

The extinguisher is supplied charged with one quart of either Pyrene fire extinguisher liquid or chlorobromomethane (CB). Both are special liquids which form a heavy, dry, cohering blanket of fire-smothering vapour immediately they reach a temperature of 200° F. or more. These liquids are non-damaging to materials or mechanisms and do not readily deteriorate or freeze. Both are effective against all fire outbreaks involving motor vehicles, and small petrol, paraffin or alcohol fires. They may also be used with safety against outbreaks involving electrical apparatus.

The Pyrene Co., Ltd., 9 *Grosvenor Gardens, London, S.W.*1.

New Welding Electrodes

THREE new electrodes suitable for either A.C. or D.C. supply have been added to the Quasi-Arc range.

Ferroloid No. 3 electrodes are a development in the 55/45 nickel-iron class, and are intended especially for strength welding of ordinary grey and special duty cast iron such as Meehanite and S.G. Iron. They can also be used for promoting joints between such irons and mild steel or nickel-bearing materials. Ferroloid No. 3 electrodes are made in size 12, 10 and 8 s.w.g. in 12, 12 and 15 in. lengths, respectively, and are of particular value to the iron-casting and foundry industries.

Chromoid No. 4 electrodes, of particular interest to the chemical engineering and oil refining industries, deposit weld metal of 18/8/3 chromium-nickel-molybdenum composition stabilised with niobium, and they conform to the requirements of I.C.I. Spec. No. M.154G, Class E. They are designed for the all-position welding of acid-resistant steels of the 18/8/3 chromium-nickel-molybdenum class, with or without titanium or niobium stabilisation. Weld metal soundness to Class I radiographic standard is obtainable with any work position

or type of welding supply. The electrodes are made in 12, 10, 8 and 6 s.w.g., in 12 in. lengths.

Chromoid No. 5 electrodes deposit fully-austenitic stainless steel of 25/20 chromium-nickel composition, and the weld metal contains less than ½% ferrite. They are particularly suitable for use in the chemical engineering and oil refining industries. They have been primarily developed for all-position welding of stressed components in 25/20 chromium-nickel heat and corrosion resistant steels, such as Immaculate 5. They are also recommended for joining mild and stainless steels and other dissimilar steels, and for welding certain stainless clad steels, notably the Colclad series. Welds to Grade A radiographic standard can be obtained, and the electrodes are made in sizes 12, 10 and 8 s.w.g. in 12 in. lengths.

Quasi-Arc, Ltd., Bilston, Staffs.

Graphite Anodes for Cathodic Protection

CORROSION annually costs industry millions of pounds in replacement or maintenance of buried or submerged metal structures. Most of this destructive corrosion can be prevented by the use of the impressed method of cathodic protection. Carbinert graphite anodes are being supplied extensively to cathodic protection engineering organisations by the Morgan Crucible Co., Ltd., and are being used in increasing numbers for the protection of metal structures against electrolytic corrosion.

Carbinert anodes are rendered completely impervious by wax or resin impregnation to give the maximum possible working life in all types of soils and waters. Applications for which these anodes have been used include the protection of buried pipelines, jetties, wharfs, storage tanks and ships hulls. They are stocked in sizes ranging from 2½ in. in diameter to 6 in. in diameter, in lengths up to 80 in. This ensures minimum delay in meeting the demands of an ever increasing number of installations. Only for very large installations and demands outside the stocked range is it necessary to manufacture anodes specially to meet an order. Even under these circumstances such manufacturing facilities are available that there is little delay in supplying anode requirements.

*The Morgan Crucible Co., Ltd., Battersea Church Road, London, S.W.*11.

Air Barrier Mask

AN air barrier mask designed by the R.F.D. Co., Ltd., is intended to give protection under extreme conditions of paint spraying, metal spraying, stove enamelling, etc., where an ordinary face shield or goggles would become quickly fouled.

The mask protects the respiratory organs, eyes, ears and tender skin against heavy concentration of vapour, fumes, dust and dirt. In operation, clean air under pressure continually enters the hood and exhausts through the vision opening, thus setting up a barrier of air. This constant outward flow of air ensures absolutely clear vision. The hoods which are expendable and inexpensive, will at first be in translucent polythene, but will later also be supplied in paper and cloth if justified by demand. A compact regulating valve will enable the operator to control air pressure and also allow the mask to be supplied from a spraygun air supply hose if required.

Prototypes have been tried out by a number of leading paint and metal spraying companies and it is claimed that they have been very successful, as the operators find them comfortable and do not mind wearing them. Production of these masks is due to commence in July of this year.

R.F.D. Co. Ltd., Protective Clothing Division, Godalming, Surrey.

Spatter Adhesion Preventative

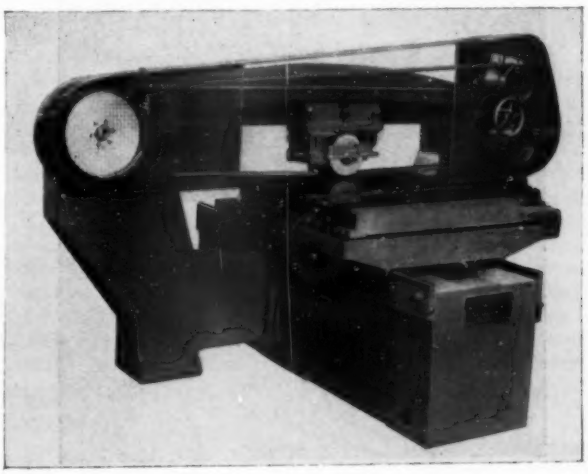
AMBERSIL, the aerosol-packed silicone spray mould lubricant, which was introduced last winter by Amber Oils, Ltd., has found a new and entirely different market. Users have found that, in addition to its primary function as a mould release agent, Ambersil Formula I is particularly successful as a means of preventing spatter adhesion during welding operations. For this purpose the following advantages are claimed: (*a*) the aerosol dispenser ensures a clean, efficient method of application requiring the minimum of equipment and preparation; (*b*) Ambersil can be left on the metal after welding has been completed; (*c*) only a very thin film of Ambersil is needed, and the aerosol dispenser ensures that this is imparted with the utmost economy; (*d*) Ambersil, which has a flash point of 600° F., does not interfere with the weld and is resistant to the cooler splatter.

Ambersil Formula I is a pure methyl silicone fluid, with high lubricity, high heat resistance and low surface tension. It is colourless, odourless, non-toxic, non-volatile, water repellent, chemically inert, and highly resistant to oxidation and shear breakdown. With a spontaneous ignition temperature in the order of 900° F., it is virtually non-inflammable.

Amber Oils, Ltd., 11A *Albemarle Street, London, W.*1.

Abrasive Finishing Machine

A NEW machine for abrasive finishing on large flat surfaces, developed by Taylor Tools, and Supplies, Ltd., will operate quickly and efficiently on metal, plastic or wood and is claimed to be economical and efficient on abrasives paper belts, the least expensive type. If necessary, a belt can be changed in less than a minute.



The table surface is 36 × 36 in. and the machine will polish the full width : lengths greater than that of the table can be accommodated by moving the work piece on the table. The contact roll or pad is supported on a rigid bridge and traversed by air-hydraulic mechanism, giving an infinitely variable speed. The table feed is automatic, and the contact pressure can be varied to suit the materials being processed and the finish required. The controls are simple and safe to operate and conveniently placed, so that the operator has complete control at all times.

The machine illustrated is operating with electromagnetic clamping for surface polishing and finishing of suitable objects. It can be used with other types of securing mechanism as required.

Taylor Tools and Supplies, Ltd., Altrincham, Cheshire.

Fork Lift Truck

A NEW fork lift truck has been added by Matling, Ltd., to their wide range of mechanical handling equipment. Known as model RFLT2, it is rider controlled and has a maximum lifting capacity of 3,000 lb. at a load centre of 20 in. In common with all other Matling units it has been designed to provide maximum manoeuvrability in restricted spaces.

The truck is powered by a 24-volt battery which operates a heavy duty constant speed reversing motor. Transmission to the single rear wheel is through a multi-plate clutch and a gear box providing three speeds. Lifting and tilting are effected hydraulically by means of a separate 24-volt series wound motor direct coupled to a gear type pump which supplies pressure to the lifting and tilting jacks operating the telescopic mast assembly. The hydraulic tank is placed under the driver's seat and incorporates a pressure relief valve which prevents the operator from lifting an excessive load.

The layout of the truck controls has been carefully studied with a view to eliminating operator fatigue. Various safety devices have been incorporated to ensure foolproof action. A key switch must be turned and the " dead man " pedal actuated before the equipment can be operated. The electrical circuit is broken when the brake pedal is depressed and when the charging plug is left open. Mechanical interlocks are provided on the tilting and lifting control levers. Positive stops inside the jacks ensure that neither load carriage nor mast can overtravel.

Matling, Ltd., 28 Caxton Street London, S.W.1.

Differential Pressure Transducer

THE Evershed Type ER.125 differential pressure transducer converts differential pressures into an electric direct current signal suitable for remote indication, or as the " measured value " signal for an Evershed electronic process controller. This transducer's output may also be employed as one of the input variables for the Evershed simple analogue computor. The materials employed in the construction of the transducer make it suitable for application to processes involving oil and viscous or corrosive fluids, as well as water, steam or gases. The Type ER.125 transducer will operate over protracted periods with the minimum of maintenance, and it is constructed to withstand severe operating and climatic conditions. Its maximum temperature rating is 177° C.

The advantages of the Evershed electronic repeater system on which this transducer is based fully apply, and it is thus unaffected by variations in the mains voltage or frequency, and no inaccuracy results from changes in the transmission line resistance or the inclusion of additional display or recording instruments. The continuously adjustable ranges covered by Type ER.125 transmitters are 0–5 w.g., 0–50 w.g. and 0–200 w.g. Maximum working pressures up to 1,000 lb./sq. in. The accuracy is ± 1% of F.S.D., and the output signal can be arranged as either 0—15 mA. or 0–30 mA.

Evershed & Vignoles, Ltd, Acton Lane Works, Chiswick, London, W.4.

Portable Deminrolit Plant

DISTILLED quality water without use of heat or power is obtained from the new Mark V Portable Deminrolit plant. Incorporating a dial type conductivity tester and supplying up to 6 gallons of pure water hourly, the Mark V Portable is particularly suitable for laboratory and small process work. Basically, it consists of two columns of ion exchange material. When raw water is passed through the first column, containing Permutit Zeo-Karb cation exchange material, the mineral salts in the raw water are converted to their corresponding acids. These acids are then passed down through the second column, containing Permutit De-Acidite ion exchange material, which absorbs the acid. The demineralised, or de-ionised, water which results from this process is of distilled quality.

The Mark V Portable is easy to operate, thoroughly reliable, and the only running costs involved are the small quantities of acid and alkali required for regenerating the ion exchange materials. The Permutit Zeo-Karb and De-Acidite ion exchange materials are of proved quality and very robust—assuring the plant a long effective life.

The Permutit Co., Ltd., Permutit House, Gunnersbury Avenue, London, W.4.

CURRENT LITERATURE

Book Notices

THE REDUCTION AND PRESENTATION OF EXPERIMENTAL RESULTS

By J. T. Richardson. Published as B.S. 2846 : 1957 by the British Standards Institution, 2, Park Street, London, W.1., 10s.

THE expression of experimental results is an art which will demand more and more skilled exponents if Britain is fully to seize the opportunities which technological progress offers. In science and technology—as in literature and the drama—to have something to say is not enough ; it must also be well said. This new book, by a member of the scientific staff of Imperial Chemical Industries, fulfils this exacting demand. Expertly and readably, he develops its theme : that uniformity of procedure is essential, both in summarizing and comparing results obtained in the many determinations made in engineering production, and in other kinds of scientific and technological investigation. Guidance is given on a wide range of types of experiments, e.g. in the laboratory or the factory, in research or in workshop production, in small or large scale observations, or in a series of repetitive tests such as those made for the quality control of products at different stages of manufacture.

Of particular interest is the chapter on frequency distribution—a subject which deals with the grouping and sorting of observations, and is useful in presenting the results of large numbers of observations in a condensed form. The evaluation and use of the quantities " arithmetic mean " and " standard deviation " for presenting in brief form the results of an experiment are well illustrated. Detailed examples provided by the author relate to such widely divergent subjects as the compression strength of concrete cubes, the phosphorus pentoxide content of a fertilizer, and the breaking strengths of cotton fabric strips and of hard-drawn copper wire.

Another section of the book deals with the reliability of the results of an experiment expressed in terms of " confidence limits," i.e. the limits within which it is estimated that the true values of the arithmetic mean and the standard deviation lie, when associated with a stated probability. A most useful application of the recommended form of presentation of experimental results is described in relation to the repetitive tests necessary for the control of the quality of products during manufacture. The use of control chart techniques is briefly summarized, and illustrated with examples.

Mr. Richardson's timely work promises to enjoy a wide readership—among students as well as those of more mature experience.

ALUMINIUM IN ELECTRICAL ENGINEERING

Applications Brochure No. 10 of The Aluminium Development Association, 33 Grosvenor Street, London, W.1. 72 pp., numerous illustrations. 4s. 6d.

The primary object of this publication is to show the range of existing applications of aluminium and its alloys and their potentialities in the electrical engineering field. At the same time, certain technical aspects are briefly discussed, in particular, the rapid and successful development of jointing techniques.

A brief statement of the case for aluminium, covering economic and technical factors, is followed by summaries of relevant British Standards and of the electrical, mechanical, chemical and fabricating properties of aluminium materials for electrical uses. The survey of applications, which forms the major portion of the brochure, is grouped under four main headings : conductors and cables ; telecommunications ; stationary plant ; and rotating machinery.

The section on conductors and cables discusses in turn overhead conductors and insulated cables, and under both subdivisions there are numerous illustrations of joining equipment and technique. Information is given on cable sheathing, both for ordinary and pressure-type cables. In this section, also, are included illustations of industrial, domestic and transport applications of aluminium in the electrical field. Busbars and busbar jointing are treated as part of stationary plant, where they are associated with transformers, reactors and switchgear. An outline of principles by which the applicable jointing process operate is presented in the concluding section, subdivided into : compression jointing, bolting, soldering, brazing, welding, and the jointing of anodised conductors. The Appendix tabulates the properties of materials used in electrical engineering applications : (*a*) for conductors and sheathing ; and (*b*) for constructional purposes.

Trade Publications

THE majority of British motor car manufacturers now use the Bonderizing process of corrosion inhibiting paint bonding on the body work of their vehicles. This is carried out by either immersion or spraying, or a combination of the two. On a more modest scale, Spray Gun Bonderizing can be used, but this is rather wasteful for repair work. For this purpose the Brush Bonderizing process has recently been developed in which, as its name implies, the solution is applied by means of a brush. A leaflet describing this technique, reprinted from *Service Station*, has recently been issued by the Metal Finishing Division of the Pyrene Co., Ltd.

JUST over ten years ago a new company, Fielden Electronics, Ltd., was founded to produce an instrument for measuring the moisture content in yarn. Since that time the enterprise has expanded considerably and moisture measurement has been extended from textiles, to a variety of substances in bulk or granular form. Then followed level indicating and controller devices, the proximity meter, the servograph (an electronic recorder), the pyroservograph and other special electronic instruments. To mark this tenth anniversary, the company have issued a booklet entitled " Ten Amazing Years " which includes a brief history of the company and particulars of its various products and their applications.

MOST of our readers are familiar with the fact that the Wakefield Group are the makers of Castrol motor oils and Wakefield-Dick industrial and marine lubricants.

Perhaps less known is the fact that Wakefields have also been, for nearly 60 years, large-scale manufacturers of lubricators and lubrication equipment. The extensive scope of this side of their business is demonstrated in a new publication, "Wakefield Lubrication Equipment Speeds Production." This is an attractive, 24-page brochure which deals in turn with oil and grease lubricators, mobile lubrication equipment, the lubrication of pneumatic equipment, and locomotive and automotive lubrication. Equipment of practically every type is shown in action in over 50 photographs.

STARTING several years ago with a twin column hydraulic press for mounting metallurgical microspecimens in plastic, Apex Construction, Ltd., 15, Soho Square, London, W.1., have now developed a number of items of equipment for use in the preparation of such specimens. A recently published catalogue, No. P56, gives particular of a range which includes four mounting presses, together with accessories such as moulds, heaters, coolers and mounting media; rotary grinders; belt surfacers; and hand grinders. Of the two metallographic polishing machines detailed, one has been designed for the simultaneous polishing of as many as 12 specimens.

THE first number of *Efco-Udylite Review* recently made its appearance. It is ten years since the Electro-Chemical Engineering Co., Ltd., became responsible for the distribution of the Efco-Udylite processes and equipment in Europe and the British Commonwealth. The articles appearing in the *Review* are extracted from news letters which go out periodically to all Efco-Udylite distributors. By this means it is hoped to keep customers throughout the world in contact with the latest developments in metal finishing techniques. The Udylite Corporation in Detroit is the largest research and development unit engaged in the industry and has developed, among other things, Zero-Mist, bright nickel, bright zinc, bright copper and cadmium processes which have been widely adopted.

WE have received from Gibbons Brothers, Ltd., an illustrated leaflet dealing with reverberatory melting furnaces; duplex furnaces, consisting of melting bath and holding bath; holding furnaces; and air furnaces for melting large size iron scrap.

THE April, 1957 issue of *Rem-Cru Titanium Review* makes reference to a new titanium alloy containing 6¼% aluminium and 3¾% molybdenum, which is claimed to have improved elevated temperature strength, excellent time-temperature-stress-stability, deep hardenability, and excellent heat treatment properties. Other features deal with warm spinning of titanium, resistance to choloride corrosion, pickling baths for more rapid removal, and the use of titanium as a cathode in electrolytic reduction.

WE have received from the English Electric Co., Ltd., two new publications, Nos. SG/338 and SG/339, entitled respectively An Outline of Electrical Distribution Systems and Protective Devices Applied to Electrical Switchgear. A third publication dealing with industrial distribution substations will be issued in due course to complete this series which is being published to summarise the factors involved in designing a new, or extending an existing, electrical distribution system. Publication No. SG/338 describes the general problems which usually decide the type of scheme to be used and then gives a number of typical systems which can be used as a basis for almost every individual requirement. Publication No. SG/339 is a review of the more general types of electrical protective schemes for systems up to 11 kV., 250 MVA., and it gives general recommendations for the protection of such items of equipment as transformers, motors and feeders.

IT is almost 25 years since the first "Speedivac" pump left the factory of what is now Edwards High Vacuum, Ltd. Today there are more than a dozen different models and these, together with large industrial high vacuum pumps displacing up to 20,000 litres per minute, are described in a 24-page booklet recently produced by the company. Sufficient information has been included to enable users to select pumps for standard laboratory and industrial applications, and several pages are devoted to the various accessories which are available.

AERO RESEARCH, LTD., manufacturers of adhesives and honeycomb for aircraft structures, have produced a 16 mm. colour film describing the Redux bonding process. The method of use of Redux and the characteristics of bonded structures are described in detail, and typical bonded components and bonding plants are shown. Reference is also made to honeycomb sandwich structures. The film, which runs for 17 minutes, is available in French, German, Italian and Japanese (for magnetic reproduction), as well as in English (optical reproduction). Copies are available on loan to aircraft manufacturers, technical colleges and other interested organisations from Aero Research, Ltd., Duxford, Cambridge.

A FEATURE of the May issue of *The Nickel Bulletin* is a series of abstracts of papers presented at the recent meeting of the Institute of Metal Finishing dealing, *inter alia*, with the mechanism of levelling in electrodeposition and with the influence of electrodeposited coatings on the fatigue properties of steel. Among the abstracts relating to heat and corrosion-resisting materials are reports on the use of electrodeposited coatings for protection of molybdenum from oxidation, the use of stainless steel and high-nickel alloys in the chemical industries and the welding of austenitic steel tubing for high-temperature service.

Books Received

"Extraction and Refining of the Rarer Metals." A Symposium on Extraction Metallurgy of Some of the Less Common Metals arranged by the Institution of Mining and Metallurgy, held on 22nd and 23rd March, 1956, at the Royal Society of Arts, John Adam Street, London. 444 pp. inc. name and subject indexes. 22 papers and discussion. London, 1957. The Institution of Mining and Metallurgy. 60s. (U.S. $8.50).

"Précis de Métallographie Appliquée (Aciers et fontes). By A. Roos. 381 pp. inc. numerous illustrations. Paris, 1957. Dunod. 4.250F.

"Die Giesserei- und Metallindustrie der Schweiz." 152 pp. Zürich, 1957. Verlag für Wirtshaftsliteratur GmbH. Obtainable in Great Britain from H. K. Lewis & Co., Ltd. 25s.

"Metal Machining." By L. E. Doyle. 511 pp. inc. index and numerous illustrations. London, 1957. Longmans, Green & Co., Ltd. 75s. net.

LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

JULY, 1957. Vol. LVI, No. 333

Some Recent Advances in the Analysis of Cast Iron and Foundry Materials

By W. E. Clarke, A.R.I.C.
British Cast Iron Research Association.

This article is based on a paper presented to the Midlands Section of the Society for Analytical Chemistry during the last session, in the course of which the author discussed sampling; the use of high frequency induction heating in carbon determination by the combustion method; and rapid methods for the determination of magnesium. The sections on trace elements in cast iron, and aluminium in cupola slags and cast irons have been added subsequently.

DURING recent years the Methods of Analysis Sub-Committee of the British Cast Iron Research Association (B.C.I.R.A.) has carried out much work on the revision and improvement of methods in use for the chemical analysis of cast iron. Most of the advances have been in matters of detail and consist of improvements to the accuracy of existing methods. Some of the larger projects which have been carried out by the Sub-Committee, or in the laboratories of the Association, as well as some of the work on the analysis of nodular irons both at the B.C.I.R.A. and elsewhere, are discussed here.

Sampling

Cast iron being an alloy of iron and carbon, one of the analyses most frequently called for is the determination of the total carbon content. In ordinary grey iron the carbon is present in several different forms, and one of these, graphite, often causes difficulty in obtaining a representative sample. The normal method of sampling is to drill the specimen for analysis and to use these drillings either immediately or after some further treatment, such as sieving or grinding, designed to produce a more uniform particle size in the sample. Whilst drillings give reproducible carbon results for many irons, it is virtually impossible to obtain any reproducible figures with such materials as ingot moulds, haematite pig irons and nodular irons. Westwood and his collaborators[1,2] have shown that in such cases a better result can be obtained by employing a small solid sample cut from the pig or casting.

The B.C.I.R.A. Methods of Analysis Sub-Committee has investigated different sampling techniques in order to establish when solid samples must be employed and when it is possible to use drillings without significant loss of accuracy. The sampling techniques investigated were :—

(*a*) Solid samples.

(*b*) Drilling with $\frac{1}{8}$ in. drill at 25 r.p.m. to a depth of about 1 in. and using the whole of the drillings. (This was designed to avoid loss of graphite, which could occur during the weighing of a sample from a bulk sample of drillings.) This method was abandoned early in the investigation since it was found that it gave no significant improvement in reproducibility.

(*c*) Drilling with a $\frac{1}{2}$ in. drill at 100–150 r.p.m. through a complete cross-section of the sample.

(*d*) Drilling as in (*c*), followed by separation of the drillings into coarse and fine fractions on a 60 mesh sieve. For the determination either proportionate parts were weighed out, or separate determinations made on each fraction and the overall carbon content calculated.

(*e*) Drilling followed by grinding in a steel mortar until all the drillings passed through a 30 mesh sieve.

Fig. 1 shows diagrammatically the type of results obtained with a normal flake graphite iron in four of the co-operating laboratories. The results obtained on untreated drillings were not significantly lower than on solid samples, but after sieving or grinding the results were definitely lower. This is quite simply accounted for by loss of fine graphite dust during these processes. The scatter of results also increased when the drillings were treated in either of these ways.

The results from eight collaborating laboratories on an ingot mould sample are illustrated in Fig. 2. The enormous scatter of results on drillings is evident, and it is further emphasised when it is considered that each of these results is itself an arithmetical mean. The mean value of the eight sets of results is more than 0·3% lower than the mean value using solid samples.

The principal factor leading to this discrepancy is the size of the graphite flakes in the ingot mould casting. Figs. 3 and 4 illustrate the graphite flakes in a normal casting and in a heavy casting like an ingot mould. The larger graphite flakes lead to a much greater danger of loss of graphite during sampling, even when solid pieces are used.

A factor influencing the size and distribution of graphite is the size and weight of the casting, the influence

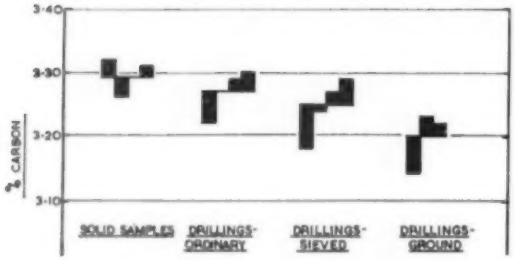


Fig. 1.—Normal flake graphite iron casting.

Figs. 1 and 2.—Influence of different sampling techniques on carbon results.

of varying section size on carbon results being illustrated in Fig. 5. When the section size reached about 2 in., there was a significant loss of reproducibility on drilled samples between laboratories. This became very pronounced at a section size of 3 in.

Graphite can also exist in grey irons in another form, i.e. nodular graphite. This type of graphite is illustrated in Fig. 6. It might be thought that with this type of structure it would be possible to use drillings, but that this is not the case can be seen from Fig. 7, which presents diagrammatically the results obtained on two nodular graphite irons. The lack of reproducibility and the low results obtained on nodular iron drillings seems to be due to the presence in the drillings of a small amount (less than 5%) of very fine material with a high carbon content (see Table I).

TABLE I.—RELATIVE AMOUNTS AND CARBON CONTENTS OF COARSE AND FINE FRACTIONS IN DRILLINGS FROM FLAKE AND NODULAR GRAPHITE CAST IRONS

Type of Graphite	Amount (%)		Carbon Content (%)		Calculated Carbon Content of Iron (%)	Actual Carbon Content of Iron (%)
	+ 60 mesh	− 60 mesh	+ 60 mesh	− 60 mesh		
Flake	76·1	23·9	3·29	3·38	3·31	3·36
Flake	82·3	17·7	3·23	7·57	4·00	4·25
Nodular	97·2	2·8	2·92	6·60	3·02	3·19
Nodular	98·7	1·3	2·67	11·37	2·78	3·08

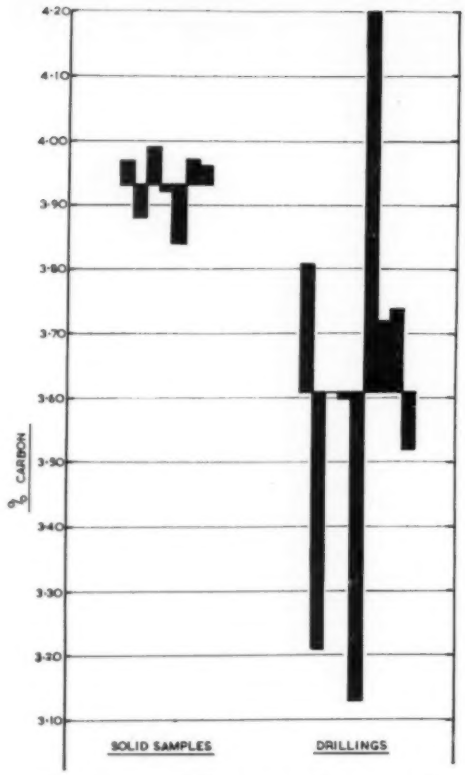


Fig. 2.—Coarse flake graphite iron in ingot mould casting.

The findings of the Sub-Committee have been published[3, 4] and can be summarised as follows :—

(1) For the most accurate results, solid samples should be employed. If liquid metal is available for sampling, pin samples should be cast, using a mould such as that described in B.S. 1837 : 1 : 1952, Amendment No. 1. Otherwise, small pieces weighing between 1 and 2 g. and with a cross-

Reduced ⅓ linear in reproduction

Fig. 3.—Microstructure of normal flake graphite iron casting. Unetched. ×100

Reduced ⅓ linear in reproduction

Fig. 4.—Microstructure of coarse flake graphite iron in ingot mould casting. Unetched. ×100

section of about $\frac{1}{8}$ in. square should be cut, either with a saw or a hollow miller. Pin samples gave the most reproducible results.

(2) For ordinary routine determinations on fine or medium flake graphite irons, drillings may be employed. A section size of 2 in. can be regarded as the safe upper limit for the use of drillings. The drill speed should not exceed 150 r.p.m. and the sample should be taken without any further preparation of the drillings. The samples for carbon determination should be taken after thoroughly mixing the drillings and before any other determination samples.

(3) With nodular graphite irons the use of solid samples is essential.

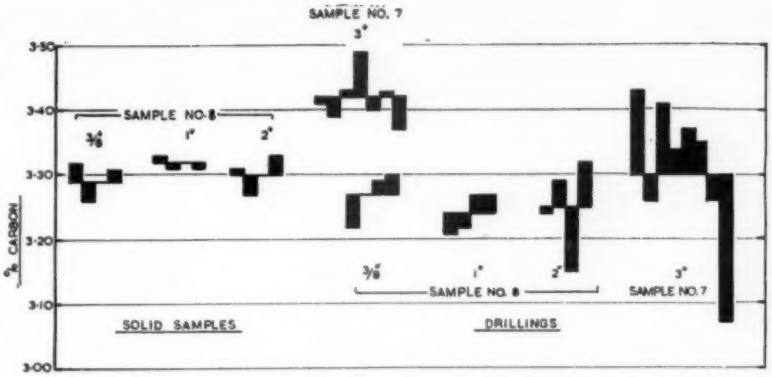


Fig. 5.—The influence of section size on carbon results.

R.F. Heating for Combustion Carbons

The use of high-frequency heating for the combustion of iron samples in the determination of carbon and sulphur has been investigated recently in the U.S.A. and in Sweden[5-7]. As no suitable radio-frequency heating unit was available commercially in Great Britain an apparatus was built at the Association. An illustration of this apparatus arranged for the determination of total carbon is given in Fig. 8, and a close-up of the double work coil in Fig. 9: details of the construction of the apparatus are given in a paper by Clarke and Rew.[9] High frequency induction heating of cast irons and steels is due to hysteresis and eddy current losses in the sample being heated. Above the Curie point the permeability of the sample falls to unity and heating is by eddy currents only. With the physical arrangement of sample relative to the work coil in such an apparatus as this, it is inevitable that poor coupling exists, as the sample has to be contained in a covered boat or thimble and this latter contained inside a combustion tube. After reaching the Curie point a noticeable drop in power input is evident, any further rise in temperature necessary for burning off the sample being materially assisted by the heat of reaction, possibly aided by arcs set up between adjacent particles of sample.

Tests have been carried out at the Association's laboratories using steel samples, grey and white cast iron drillings and solid samples, white iron powders, highly alloyed irons and ferro-alloys. The effect of using different fluxes and the correct conditions for complete combustion were investigated,[9] and the results of the investigation may be summarised as follows:—

(1) With this type of heating a small proportion of the carbon in the sample is oxidised only to carbon monoxide, not dioxide. (The presence of this monoxide was confirmed at the B.C.I.R.A. by using an infra-red gas analyser.) The magnitude of this proportion is indicated in Table II. This partial oxidation can be overcome by passing the gases over a catalyst to oxidise monoxide to dioxide.

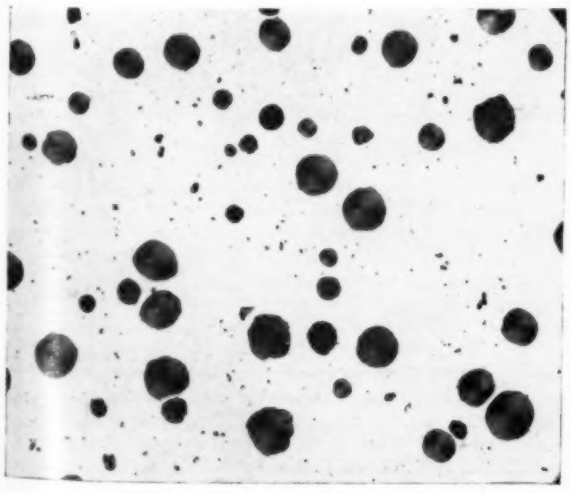


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Fig. 6.—Microstructure of nodular graphite iron. Unetched. ×100

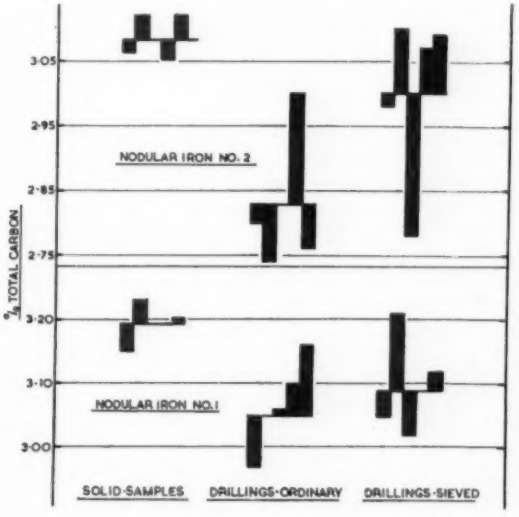

Fig. 7.—Influence of different sampling techniques on carbon results in the case of nodular graphite irons.

Fig. 8.—Radio frequency induction heating apparatus.

(2) Normal sized drillings do not require any flux, but in general combustion is improved by wrapping in a sheet of tinfoil weighing about 1 g.

(3) With finely divided materials, e.g. powders less than 60 mesh, tinfoil wrapping alone is not sufficient, and either 1 g. of pure iron drillings or 1 g. of red lead has to be added to ensure combustion.

(4) With ferro-alloys (e.g. ferro-chromium or ferro-manganese) tinfoil + 1 g. of pure iron is required.

(5) Solid samples can be burnt off satisfactorily if tinfoil + 2 g. of red lead is used as flux.

(6) In order to get satisfactory combustion of simultaneous duplicate determinations, a short period of preheating before the introduction of oxygen is needed. This ensures that both samples begin to burn together.

(7) When conditions are satisfactory, combustion usually takes from 1¼ to 2 minutes: a shorter period indicates incomplete combustion. Combustion tubes can be much shorter than with conventional heating, since the tube itself does not become very hot. The total time for a duplicate determination is about 5 minutes plus weighing time.

TABLE II.

Description of Sample	Carbon Content (%)	Catalyst	Carbon Found (%)	
Carbon Steel	1·20	None	1·15	1·15
			1·18	1·16
		Heated Platinum Wire	1·19	1·20
			1·18	1·22
		Heated Silica Tube	1·20	1·22
Grey Cast Iron ..	2·83	None	2·65	2·66
		Heated Tube	2·88	2·81

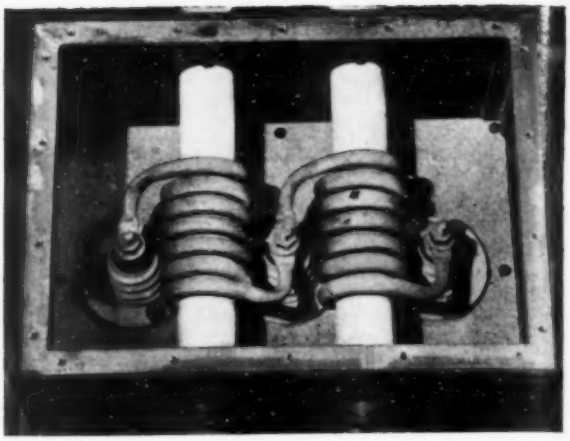

Fig. 9.—The coils in the radio-frequency induction heating apparatus.

(8) The chief disadvantages are :—

(*a*) The incomplete combustion to carbon dioxide, necessitating the addition of a catalyst tube.

(*b*) Cracking of normal type combustion boats due to thermal shock.

Table III gives a selection of results obtained using this type of heating.

Rapid Methods for Magnesium

The increasing use of nodular iron has necessitated the development of rapid methods for the chemical determination of magnesium, since not all laboratories have spectrographic equipment, and the gravimetric method published by Westwood and Presser,[10] although accurate, is too time-consuming for routine purposes. Consequently, a number of more rapid procedures have been developed.

Green[11] has proposed a method in which magnesium is determined by titration with E.D.T.A. after separation or masking of interfering elements. In order to effect a rapid removal of iron without the need for special

TABLE III.—CARBON DETERMINATIONS USING R-F INDUCTION HEATING

Description of Sample	Carbon Content (%)	Flux Used	Carbon Found (%)
Steel Drillings	1·20	None	1·23
		Tin	1·21
Grey Iron Drillings (50–60 mesh)	2·83	Tin	2·86
Grey Iron Drillings (coarse)	3·40	None	3·40
		Tin	3·42
White Iron Drillings ..	2·47	None	2·46
White Iron Powder (80 mesh)	3·05	Tin	1·31
		Tin + 1 g. iron	3·05
		Tin + 1 g. red lead	3·03
Solid Sample (Grey Iron)	3·79	Tin	Nil
		Tin + 1 g. iron	3·85
		Tin + 2 g. red lead	3·79
Austenitic Iron (17% Ni)	3·09	None	3·05
20% Chromium Iron ..	2·89	None	Nil
		Tin	2·94
30% Chromium Iron ..	2·01	Tin + red lead	2·07
80% Ferro-Chromium ..	5·09	Tin	Nil
		Tin + 1 g. iron	5·10
		Tin + red lead	Nil
Ferro-Manganese	6·58	Tin + 1 g. Iron	6·65

apparatus, he uses a zinc oxide separation. The sample is dissolved in nitric acid and fumed with perchloric acid. After diluting with water, zinc oxide, in excess, and ammonium persulphate are added to precipitate iron and manganese. The volume is made up to 500 ml. and 250 ml. are filtered off. Sodium cyanide is added to mask the excess zinc and nickel and Tiron to complex any titanium present. After adjusting the *p*H to 10, an excess of E.D.T.A. is added and back-titrated with standard magnesium solution. The method has the disadvantage that it is non-stoichiometric, since magnesium is adsorbed on the zinc oxide precipitate, and in order to standardise, 10 g. samples of iron, to which known amounts of magnesium have been added, need to be carried through the procedure. This disadvantage is offset to some extent by the extreme rapidity of the method compared with other procedures—a determination can be completed in two hours. Also some experience is necessary before the end-point of the titration can be judged accurately. Tests carried out on the method have shown that despite these objections very good agreement with results obtained by more accurate chemical methods can be achieved by an experienced operator.

In order to avoid the non-stoichiometry of the zinc oxide method Sneddon,[12] of the B.C.I.R.A.'s Scottish Laboratories, has proposed the removal of iron and nickel by mercury cathode electrolysis, followed by precipitation of manganese with ammonium persulphate, and titration of magnesium with E.D.T.A. The use of mercury cathode electrolysis, however, tends to limit the sample weight which can be employed, unless special electrolytic apparatus is available. The present author considers that the most promising approach would be to use extraction procedures for the removal of interfering elements. Iso-propyl ether or butyl acetate can be used to extract iron, and recent work by himself on the determination of aluminium in slags has shown that quite large amounts of manganese can be extracted as diethyldithiocarbamate in organic solvents. In this way, loss of magnesium by absorption would be avoided.

A number of papers on the determination of magnesium have been published recently by German authors. Graue[13] claims that a satisfactory separation of the heavy metals can be effected by using ammonium sulphate, and that no magnesium is carried down on the precipitate. Traces of heavy metals remaining in solution are removed by precipitation on $Zr(OH)_4$. Calcium and magnesium are then precipitated with oxine, and the final determination of magnesium made spectrophotometrically with titan yellow. The time required for the procedure is stated to be three hours.

Reichert[14] has used Graue's separation preliminary to a complexiметric titration of magnesium. The sample is dissolved in hydrochloric and a little nitric acid—a 1 g. sample is used for magnesium contents greater than 0·01%, 5 g. for values between 0·005% and 0·01%, and 10 g. for magnesium contents down to 0·001%. Without filtration, the hot solution is made ammoniacal, 1–2 g. of ammonium chloride added and hydrogen sulphide passed. The precipitate is filtered off on the pump and washed once or twice. (The amount of magnesium left in the precipitate by incomplete washing is stated to be negligible.) To the warm colourless filtrate are added 1 g. of solid ascorbic acid (to reduce traces of ferric iron), 10 ml. of 10% potassium cyanide and 2 ml. of 50% aqueous triethanolamine. The volume for a 1 g. sample should now be approximately 200 ml. A further 0·5 g. of ascorbic acid is added, the solution heated and solid Eriochrome Black-T indicator (1 part per 100 parts of sodium chloride) added. The *p*H is adjusted to 10 with ammonia, and the magnesium titrated with E.D.T.A. at 60° C. The time for a single determination is claimed to be 45 minutes.

Trace Elements in Cast Iron

The significant influence exerted by trace amounts of certain elements on the properties of cast irons has recently been increasingly realised. This has led to a demand for methods for the determination of these elements when present in amounts of less than 0·1%, and frequently less than 0·01%. Work is being carried out at the Association, and to date methods have been completed for antimony,[15] lead and bismuth.[16] These methods are being published.

Antimony.—In the method for antimony the sample is dissolved in nitric acid under controlled conditions and the residue of silica and graphite is filtered off. This residue and the filtrate are then treated separately.

The residue is ignited and silica removed by volatilisation. It is then taken into solution by fusion with bisulphate, the acidity adjusted to 4N with sulphuric acid, and the determination completed spectrophotometrically as iodide. The filtrate is treated with potassium permanganate to oxidise combined carbon and the excess permanganate reduced with hydrogen peroxide. The *p*H is now adjusted to 1 and antimony co-precipitated on manganese dioxide formed by addition of permanganate. After filtering, the precipitate is redissolved and tested for iron. If the iron content is less than 0·05 g., the acidity is adjusted and the determination completed as in the residue. If more than 0·05 g. of iron is present a second co-precipitation is carried out.

The correct conditions for separation were examined, as well as the conditions for the spectrophotometric determination as iodide. Interferences were studied and it was shown that the interference from bismuth was negligible under the given conditions. With the spectrophotometric finish the lower limit is 0·001% antimony. By using a polarographic finish it seems very likely that this could be lowered by several orders of magnitude.

Lead and Bismuth.—In Rooney's method for trace amounts of lead and bismuth, the iron is first separated by extraction with butyl acetate from hydrochloric acid solution. Lead and bismuth are then extracted as their diethyldithiocarbamate complexes with chloroform from ammoniacal tartrate/cyanide solution. The lead and bismuth are then determined simultaneously with a cathode ray polarograph using acid tartrate base electrolyte. For the successful determination of trace amounts of these elements, very careful attention to the purity of reagents is essential, and a detailed study of this problem has been made by Rooney. Using specially purified reagents the lower limits for lead and bismuth are theoretically 0·000001%, with, in practice, limits of 0·00001% for lead and 0·000005% for bismuth.

Aluminium in Cupola Slags and Cast Irons

As part of the Association's programme of research into improved methods for the analysis of slags, the direct fluoride volumetric method for aluminium has been investigated and a satisfactory procedure deve-

loped.[17] The sample of slag is dissolved in nitric-hydrofluoric-perchloric acid mixture, silicon volatilised as tetrafluoride, the solution buffered to *p*H 4–5 with tartrate, and iron and manganese (which were found to interfere in the titration) removed by extraction of their diethyldithiocarbamates into chloroform. The *p*H of the aqueous phase is then adjusted to 8·15, an excess of neutral potassium fluoride added and the liberated hydroxyl ion titrated with standard acid.

The same method has also been applied to cast irons containing more than 0·2% aluminium and to ferro-silicons,[18] with suitable modifications of the solution procedure. With these materials removal of the majority of the iron is by means of butyl acetate extraction.

Other work on the analysis of slags includes a complexometric method for calcium and magnesium after preliminary removal of interfering elements by solvent extraction.[19] Two solvent extraction procedures have been used. In the first, after buffering to *p*H 4·5 with acetic acid/acetate, iron and aluminium are removed by extraction as acetylacetonates, followed by extraction of manganese as diethyldithiocarbamate. In the second procedure iron, aluminium and titanium are extracted as cupferrates into chloroform at *p*H 4·5. These procedures are being tested by the B.C.I.R.A. Methods of Analysis Sub-Committee and it is hoped to publish them shortly in the *B.C.I.R.A. Journal of Research and Development*. The time taken for a determination in each method, after dissolving the sample, is about 30 minutes.

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Bureau of Analysed Samples, Ltd.

Tenth General Meeting at York

TRIBUTE was paid at the Tenth General Meeting of the Bureau of Analysed Samples, Ltd., to the memory of the late Mr. N. D. Ridsdale, founder of the Bureau, who died last year. It was largely due to the personal qualities of Mr. Ridsdale that the idea had such a successful outcome, and that so many chemists were willing to co-operate in the analytical work necessary in the preparation of standard samples.

New Standard Samples

In presenting his report on the Tenth period of Working —December 1953 to November 1956—Mr. P. D. Ridsdale (Managing Director) referred first to the new standard samples which had been issued, Ranging from pure iron granules to silica brick, and from a 5% silicon aluminium alloy to a niobium-containing permanent magnet alloy, they had all been prepared at the request of industry, most of these requests being received via the Bureau's Advisory Committee.

Without doubt, the most ambitious project undertaken had been the mild steel residual series of standards. Prepared primarily as Spectrograph Standards 11-17, but also available in the form of turnings, the series had been analysed for no less than 15 alloying elements other than carbon, silicon, sulphur, phosphorus and manganese. As could well be imagined, the production of this series presented many problems to both steelmaker and analysts, and great credit was due to both. It had taken nearly three years to complete the project, but it was hoped to issue printed certificates in the near future, now that figures for all elements except lead had been approved by the B.I.S.R.A. Analysis Committee. Such a project could not have been carried out without the co-operation of B.I.S.R.A. and its Analysis Sub-Committees, who undertook the analytical work, which in certain cases involved developing special methods of analysis for this purpose.

Other new standards in course of preparation included chemical standards for a refined ferro-manganese and a 14% manganese steel and two series of spectrographic standards—a low tungsten series ranging from 0·70% to 3·0% tungsten, and a plain carbon steel series for use with the Quantometer. The new work reflected the trend towards spectrographic standards.

Preparation of Replacements

The greatest part of the Bureau's work during the last three years had been the preparation of replacements to maintain the supply of standards which had become exhausted. As far as possible, the fact that a replacement would be required was brought to the notice of the Advisory Committee so that if members knew of or had heard of any way in which a particular sample could be improved, an attempt could be made to incorporate the improvements in the replacements. During the period under review replacements had been prepared for four carbon steels, six alloy steels, three ferro-alloys, four cast irons, one basic slag, and four pure reagents and metals.

In order to minimise the work involved and the call upon the co-operating analysts, the Bureau had endeavoured where possible, to increase the weight of bulk sample so that replacements would last for a minimum period of ten years. Due to increasing demand, however, the estimated life of a standard was often foreshortened, a typical example being the low alloy series of spectrographic standards, which were almost exhausted

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Items of Metallurgical Interest at Recent Instrument Exhibitions

The recent Instruments Electronics and Automation Exhibition at Olympia aroused considerable interest, as might be expected at a time when automatic devices are finding increasing application in industry and commerce. In this and subsequent issues, reference will be made to items of metallurgical interest exhibited at Olympia, and at the Physical Society Exhibition which, as usual, provided an opportunity for the display of new commercially available and prototype instruments and laboratory equipment.

Coating Thickness Meter

REFERENCE was made a year or two ago, in an account of the work of the British Non-Ferrous Metals Research Association, to a new type of coating thickness meter which had been developed in the Association's laboratories. This instrument is now being produced commercially by Nash & Thompson, Ltd., who exhibited it at the Physical Society Exhibition. It is capable of measuring non-destructively the thickness of electro-deposited coatings, irrespective of whether or not the coating or base metal is magnetic. Up to the present, work has been concentrated on the measurement of nickel plating on steel, brass and zinc alloys in the range $0{\cdot}5$–$1{\cdot}5 \times 10^{-3}$ in. to an accuracy of $\pm$ 15%. The presence of a thin decorative chromium deposit has no influence on the results, and means have been devised for determining the thickness of a copper undercoat if required. Indications are that the method can be used for the measurement of a wide range of electro-deposits and base metals, and possibly also for the sorting of undercoated metals.

The instrument consists of two parts, a probe unit and a sensitive D.C. amplifier incorporating an indicating meter. The probe is essentially a heated copper body on which is machined a hemispherical tip, subsequently electroplated. When the probe is applied to a plated surface thermoelectric voltages are developed due to the juxtaposition of dissimilar metals and the difference in temperature of the various interfaces. The voltage generated between the probe body and the cold base metal, after amplification, is indicated on a meter and bears a simple relationship to the plating thickness which can be determined by comparison with known standards. For most purposes a chromium tipped probe is used but when a copper undercoat is to be determined a nickel tipped probe is required in addition. Provision is made on the meter unit for the connection and control of two probes.

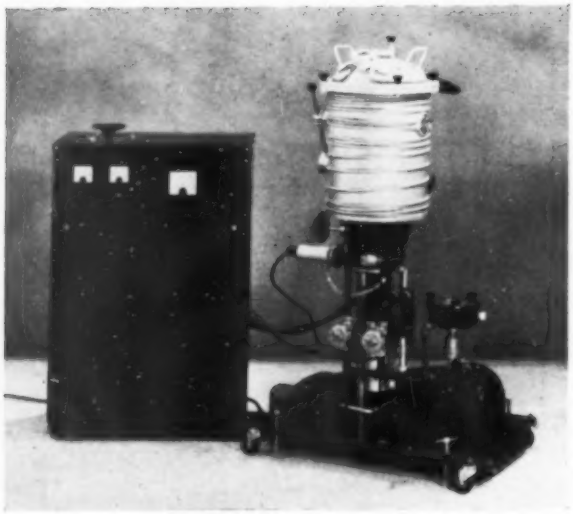
The probe is designed to be applied by hand or through a simple jig with a steady pressure, approximately normal to the surface of the test piece, the minimum workable radius of curvature on concave surfaces being 0·5 in. Manual application is satisfactory, a pressure of 5 lb. being required. In routine inspection and for highest accuracy a jig and lever system is preferred. A "cold" connection to the specimen is required to complete the circuit, this being made by the special clip provided or through the base plate of the jig.

Once the instrument has been set up all that is necessary is to clean the surface of the specimen, make the "cold" connection, apply the probe and note the reading on the meter scale, which can be calibrated directly in plating thickness. To set up the instrument two standard specimens, one for each end of the range of plating thickness, are used. The probe is applied to each in turn and the zero and sensitivity controls of the amplifier adjusted until readings are obtained at predetermined points on the scale. An hourly check should be sufficient to maintain satisfactory accuracy. Two small dry batteries are used in the zero adjusting circuit, each having an expected running life of 3,600 hours.

Coating thickness meter.

Vacuum Furnace

Since the war the vacuum casting of metals has been making major contributions to metallurgy. Thus a vacuum-cast titanium-nickel-cobalt alloy for turbine blades has significantly improved gas turbine outputs, while high speed steel for high temperature bearings has benefited from similar casting. The ½ lb. vacuum furnace shown at the Physical Society Exhibition by Edwards High Vacuum, Ltd., is available with either, or both, a furnace pot or a radiant heater assembly.



Half pound vacuum furnace.

With the furnace pot and mould resistance heated, and with the included re-crystallised alumina refractory materials supplied as standard, it is available for sintering, smelting and casting at temperaturesup to 1,700° C.—with 1,800° C. possible for short periods—thus being suitable for the majority of metals and alloys to be treated in this way.

Alternatively, a radiant heater assembly is supplied to replace the furnace pot, which gives an evenly heated working space for running up to 1,500° C.—with 1,800° C. possible with an extra power supply—for sintering brazing, and general heat treatment of many metals, especially those requiring protection from oxidation. In this latter case the cost of vacuum methods compares favourably with the provision of an inert atmosphere, while hydrogen atmospheric hazards are avoided. The even heating is of particular interest and assistance in the brazing of multiple joints of many materials and cross sections, as distortion is at a minimum.

Provision is made for working in different atmospheres, and suitable controls and sight glasses are fitted to allow full supervision of the melt. The furnace proper is mounted on a fully self-contained and mobile pumping unit, consisting of vapour and mechanical pumps, vacuum gauge, and full valving and safety features. This pumping unit, without the furnace, is adaptable for a number of high vacuum pumping duties and, being castor-mounted, can be readily transferred from place to place. Electrical supplies are brought to the furnace from a separate power unit, also castor-mounted.

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in six and a half years. The replacements for the series were well in hand, and would be in the form of 1 in. square bars to meet the requirements of both the spectrograph and the Quantometer.

Replacements for some twenty-three other standards were also in course of preparation. These included some of the older aluminium alloys, a lead base white metal, and an iron ore.

Co-operative Effort

Mr. Ridsdale concluded his report with an expression of appreciation of the work of the Honorary Advisory Committee, whose members met every six months to advise on the preparation of new and replacement standards, and provided a most valuable link with all sections of industry. Thanks were also due to the chemists who had so willingly co-operated in the analytical work and assisted in obtaining supplies of suitable raw material. Mr. Ridsdale expressed the hope that they had received some benefit from the work : at least they would have the satisfaction of knowing that they were rendering a valuable service to the metallurgical industries.

Demand Increasing

Mr. R. Chadwick (Technical Sales Manager) reported on the progress in the demand for British Chemical Standards at home and abroad, comparing the figures for the three-year period under review with those for 1953, the third year of the previous triennial period.

Exports for the year 1953 amounted to 25% of the total, and for the past three years the figures were 35%, 33% and 41% respectively. The rise of 8% in 1956 was partly due to the relaxing of export and import licensing restrictions, which created more favourable trading conditions. The countries notably affected were India, Japan and Spain. It was significant that sales to India had considerably increased during the past three years, as had those to Japan, Poland and Hong Kong. During this period, samples had been exported to no fewer than forty-five countries, the U.S.A. being the biggest overseas customer, followed by France, Poland and India.

The sample still in greatest demand was the 0·3% carbon steel, B.C.S. 239/1, whilst of the alloys steels the nickel-chromium-molybdenum steel B.C.S. 225/1 continued to head the list. The most popular cast iron was the high duty cast iron B.C.S. 234/4.

A large number of spectrographic standards had been sold to the U.S.A., and Mr. Chadwick felt they could congratulate themselves that they were the first to produce a low alloy series of spectrographic standards, of which there was no equivalent in the U.S.A.

The demand for the new mild steel residual spectrographic standards had been very encouraging, and sales of pure metals and reagents had been maintained. The demand for the pure iron had been steadily increased, proving that it had been a worthwhile addition to the list There was now a range of some seventy samples for students practising metallurgical analysis, and the demand had been maintained, although there had been no substantial increase in sales over the past three years.

Mr. Chadwick concluded by reiterating Mr. Risdale's appreciation of the work of the co-operating chemists. It was his job, not only to sell, but to maintain continuity of supplies to customers : it was only with their assistance that the Bureau was able to do this, and to serve industry, not only in Great Britain, but throughout the world.

HONEYWELL-BROWN, LTD., have moved their Manchester Branch Office to substantially larger premises at Warsall Road, Northenden, Manchester 22.